DON RIVER BIOLOGICAL INVENTORY PAST, PRESENT AND FUTURE EVALUATION

TECHNICAL REPORT # 16

A REPORT
OF THE

TORONTO AREA WATERSHED
MANAGEMENT STRATEGY
STEERING COMMITTEE

APRIL 1988

TORONTO AREA WATERSHED MANAGEMENT STRATEGY STEERING COMMITTEE MEMBER AGENCIES

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Steve Smith collected, sorted and identified all benthos samples and assisted with the electrofishing. His work forms a major contribution to this report. Thanks are extended for his cheerful perseverance with a sometimes unpleasant task.

EXECUTIVE SUMMARY

1. A fish and benthos inventory of the Don River system was undertaken in the summer of 1984 to provide a biological data base with which to evaluate proposed watershed improvements.

2. The 1984 data were compared with those from a 1949 survey of the watershed to assess the biological changes associated primarily with the urbanization of the watershed.

3. Twenty-three species of fish were found in all surveys combined. Of these, redside dace, common shiners, blacknose shiners, bluntnose and fathead minnows, and johnny and rainbow darters exhibited reduced distributions in the watershed in 1984. Brook trout could not be located in 1984.

4. The four most common species in 1984 (in order of decreasing frequency) creek chub, blacknose dace, white sucker and longnose dace were as widely distributed in 1984 as they were in 1949 and appear able to tolerate a wide range of environmental conditions.

5. An analysis of the benthic community indicated a substantial increase in the number of stations containing pollution tolerant species, particularly oligochaetes, leeches, chironomids, and isopods, since 1949.

6. In 1949 13% of the sites examined in this study had a predominantly sensitive or intolerant benthic community but by 1984 no sites were found to have a sensitive community. In 1949 65% of the sites had a moderately tolerant community compared with only 41% of the sites in 1984. Instead the majority of the sites (59%) had a predominantly pollution tolerant fauna in 1984, up from 22% found in 1949.

7. With the exception of the reaches downstream of the sewage treatment plants, the fish and benthic communities generally indicated worse conditions in 1984 than 1949. Only some of the headwater tributaries of the Main Don and the upstream reaches of the West Don exhibited any sensitivity or similarity to the 1949 survey. Fish were found in 1984 downstream of the STP outfalls which have been closed or upgraded since 1949 resulting in improved water quality in the immediate area.

8. This study suggested that species diversity and community structure have shifted in response to habitat alteration or removal, sediment loads, channelization, migratory barriers, substrate scouring from flood flows and discharges from sewage treatment plants. These observations were supported by a review of literature documenting the present and past conditions in the watershed and studies of similar situations in other watersheds.

9. Coldwater reaches in the Don are virtually non-existent and those remaining areas are now undergoing development making the potential for a trout fishery in this area unlikely.

If the environmental stability of the river can be controlled by correcting some or all of the factors outlined above, several fisheries possibilities exist. Larger individuals of those species that presently exist there - carp, suckers and creek chub - offer some recreational potential. With a greater degree of stability, members of the bass family could be established and possibly runs of migratory salmonids encouraged.

SOMMAIRE

1. Un inventaire des poissons et du benthos du réseau de la rivière Don a été entrepris à l'été 1984 dans le but de constituer une base de données biologiques pour l'évaluation des améliorations proposées au bassin versant.

2. Les données de 1984 ont été comparées avec celles d'une étude du bassin versant effectuée en 1949 afin d'évaluer les changements biologiques associés principalement à l'urbanisation.

3. Vingt-trois espèces de poisson ont été relevées dans l'ensemble des études. Parmi ces espèces, le méné long, le méné à nageoires rouges, le museau noir, le ventre-pourri, le tête-de-boule, le raseux-de-terre noir et le dard arc-en-ciel présentaient une distribution réduite dans le bassin versant en 1984, tandis qu'aucun spécimen de truite de ruisseau n'a été relevé.

4. Les quatre espèces les plus répandues en 1984 (par ordre décroissant), le mulet à cornes, le naseux noir, le meunier noir et le naseux des rapides, avaient une distribution comparable à celle de 1949, et semblaient tolérer un large éventail de conditions environnementales.

5. Une analyse du benthos a révélé une augmentation importante du nombre de postes où se trouvaient des espèces résistantes à la pollution, en particulier les oligochètes, les sangsues, les chironomes et les isopodes, depuis 1949.

6. En 1949, 13 % des zones examinées dans la présente étude présentaient un benthos en grande partie sensible ou non résistant, mais, en 1984, on n'a trouvé de benthos sensible à aucun endroit. En 1949, 65 % des zones comportaient un benthos de tolérance moyenne, par rapport à seulement 41 % en 1984. La majorité (59 %) renfermaient plutôt une faune principalement résistante à la pollution, en regard de 22 % en 1949.

7. Sauf dans les zones situées en aval des usines de traitement des eaux d'égout, les poissons et le benthos semblaient généralement en plus mauvais état en 1984 qu'en 1949. Seuls certains tributaires de la branche principale de la Don et les tronçons situés en amont de la branche ouest présentaient une sensibilité ou d'autres critères semblables à ceux relevés dans l'étude de 1949. En 1984, des poissons ont été trouvés en aval des points de déversement de l'usine de traitement des eaux d'égout qui avaient été fermés ou modernisés depuis 1949, améliorant la qualité de l'eau dans les environs.

8. La présente étude montre que la diversité des espèces et la structure du benthos se sont transformées par suite de la modification ou de la disparition de l'habitat, des déversements de sédiments, de la canalisation, de l'établissement de barrières migratoires, de l'affouillement du substrat causé par les crues et des déversements des usines de traitement des eaux d'égout.

Ces observations ont été confirmées par les études portant sur les conditions actuelles et passées du bassin versant et sur des situations semblables dans d'autres bassins versants.

9. L'apport d'eau froide dans la Don est pratiquement nul, et l'exploitation prochaine des zones restantes rend peu probable la pêche à la truite dans ce secteur.

Si l'on améliorait la stabilité environnementale de la rivière en corrigeant une partie ou la totalité des facteurs plus haut, on pourrait avoir plusieurs populations de poissons. Les grands spécimens d'espèces qui y vivent déjà (carpe, meunier et mulet à cornes) pourraient se prêter à la pêche sportive. Grâce à une meilleure stabilité, des espèces de la famille des perches pourraient être ensemencées, et le passage de salmonidés migrateurs pourrait être encouragé.

1.0 INTRODUCTION

The face of the southern Ontario landscape has changed dramatically over the past two centuries. Once the land surveys were complete, forests were cleared for agriculture, towns were settled and the rivers and their fauna responded to reflect these changes in the watershed.

Several major changes occurred concomitant with land clearing. Removal of vegetation reduced the capacity of the land to retain precipitation and meltwaters resulting in surface runoff. In forested watersheds overland flow is a rare phenomenon (Hynes 1975). Reduction in the capacity of the land to retain water has two consequences with respect to water flow; water is not held for gradual release and thus flows peak more rapidly, but are of shorter duration. Also little water is held in reserve and thus there may not be sufficient water to maintain summer baseflows resulting in once permanent streams becoming ephemeral.

As vegetative cover is removed soils are exposed to the erosive forces of surface runoff. Leopold (1968) noted that the average annual sediment yield increased from 50 to 400 tons per square mile per year as forest cover in the Potomac basin declined from 80 to 20%. The clay soils of the Peel Plain, which is the major physiographic region in the Toronto area, contribute fine particled sediment to the water courses which tend to remain in suspension or, when settled, clog interstitial spaces in gravel and rubble substrates. Among other effects, eggs laid in gravel spawning beds would eventually be suffocated by a blanket of silt.

Removal of riparian vegetation, in a region of little or no groundwater seepage, would contribute to the warming of the river. Increased water temperatures attributable to reductions in forest cover have been noted by

many authors (Dance and Hynes 1980; Edington 1965; Fritts 1961; Gray and Edington 1969; Hynes 1975; Smith 1973). Temperature preferences of many species of fish and invertebrates may be exceeded, disrupting life cycles or eliciting avoidance reactions.

In more recent years, urban lands have rapidly expanded compounding the problems imposed by agricultural development on water courses with a whole new set of environmental problems. Among the more important effects of urbanization on water courses are: the further reduction of the capacity of the land to retain water resulting in higher peak flows of shorter duration and a reduced lag time to peak flows; reduction of baseflows as little water is held in reserve for gradual release and because urban drainage may interrupt groundwater flows; channelization or other alteration of water courses to pass peak flows rapidly; channel erosion and scouring and bank destabilization associated with increased flood flows (Dickinson and Wall 1977; Mather 1981); discharge of treated domestic and industrial wastes to the river for dilution and assimilation; and storm runoff contributing often substantial concentrations of metals, pesticides, sediment, salts, nutrients and bacteria (Klein 1979; Leopold 1968).

Recently, considerable interest has been generated in the analysis, monitoring and rehabilitation of degraded aquatic ecosystems in Ontario and elsewhere in the Great Lakes basin. Streams in the Toronto area are examples of such degraded systems and have become the object of the Toronto Area Watershed Management Strategy study (TAWMS).

The TAWMS study was initiated to further document concentrations and sources of pollutants, particularly bacteria, heavy metals and pesticides, and recommend mitigative measures to maintain or upgrade existing water quality conditions in the rivers and nearshore zone of Lake Ontario in an effort to make these waters more suitable for aquatic life (Chin et al. 1981). Of the

three watersheds, Humber, Don and Mimico, being examined by the TAWMS study, the Don River is the most severely degraded. Fifteen percent urbanized in 1949, the watershed is now roughly 70% developed with urban areas extending from its headwaters to its mouth. Few watersheds are so completely urbanized. Consequently, the substantial amounts of storm water and combined sewer overflows that this area of urbanized land contributes to the Don River create a rather unique situation in this watershed. It has been intensively studied, but largely in terms of water quality, hydrology and sedimentation.

If water quality improvements for the protection of aquatic life are to be considered as one of the objectives of the TAWMS program then biological inventories prior to the implementation of some mitigative measures recommended by the TAWMS Committee were important in order to measure their success. Although it is very necessary to document concentrations of water quality parameters, particularly toxics, pollution is essentially a biological phenomenon (Gaufin 1973) affecting aquatic organisms in a variety of ways from inhibiting reproduction, eliciting avoidance reactions and reducing fitness, to killing organisms directly.

Biological investigations of streams have some advantages over the reliance on chemical or physical data alone, but it is important to realize that neither data base can replace the other. Both provide converging lines of evidence to supplement the other (Cairns and Dickson 1971). Therefore as a supplement to the extensive physical and chemical data analyses being conducted on the Toronto area water courses, a fish and benthos inventory of the Don River was proposed and subsequently funded by the TAWMS Committee.

It has long been recognized that aquatic organisms act as natural monitors. In order for an organism to persist in an area, the environmental conditions, particularly water quality, habitat and flow must permit survival

on a daily basis. Alterations in environmental conditions may gradually, or abruptly, eliminate those organisms which cannot tolerate the stress. Persistant stress may eventually shift the community to one which is tolerant of a wider range of environmental variables. Biological data available over a period of time is particularly valuable in assessing the biotic community shifts related to cultural stresses.

Historical data from a 1949 biological inventory of the river conducted by the Ontario Department of Planning and Development (ODPD) were reviewed. This information was originally collected to provide a resource data base to be used in the formation of the Don Valley Conservation Authority, now part of the Metropolitan Toronto and Region Conservation Authority (MTRCA). When the 1949 data are combined with those of 1984 an interesting comparison of community shifts in response to cultural changes in the watershed emerges.

The proposal for this study submitted to the TAWMS Committee outlined the following objectives:

1) to provide an up-to-date biological data base which can be used in conjunction with water quality data for a complete aquatic assessment;

2) to compare 1984 data with those for 1949 in order to determine the past community structure and what the impacts of continued urbanization have been; and

3) to assess the potential for fisheries rehabilitation.

2.0 STUDY AREA

2.1 The Physical Watershed

The headwaters of the river approximately 38 km from Lake Ontario, rise in the Oak Ridges Moraine, a region of coarse soils and cold spring seepage. However only a small area of the watershed drains this moraine. The majority of the basin drains the Peel Plain, an area of relatively impervious clay soils. Approximately 80% of the watershed soils are largely fine-textured clay loams (Mather 1981) which are classified as having slow-to-very slow infiltration rates (Harris 1979). The soils are underlain predominantly by shale bedrock, also relatively impervious to water.

There are two main branches in the watershed - the Little or East Don, hereafter referred to as the Main Don River, and the West Branch. Both streams rise in the moraine and receive limited cool spring seepage.

German Mills Creek parallels the Main Don from Richmond Hill to just inside the Metropolitan Toronto boundary at Steeles Avenue.

Several smaller tributaries, Wilket Creek and Taylor or Massey Creek rise in the Peel Plain, now within Metropolitan Toronto. The watershed is shown on Figure 1.

A steep gradient is maintained through much of the river's course. Between the source and Highway 7 (first 10 km) the river falls approximately 7 m/km. From Highway 7 to the forks (24 km) both the East and West Branches fall about 4.2 m/km. It is only in the last 10 km (forks to the mouth) that the gradient falls to approximately 1.25 m/km (ODPD 1950). The latter part of this stretch, particularly the channelized portion of the river and the Keating Channel, are the major depositional zones along the river's course.

The Don River watershed takes on a considerably different form now than that which would have been found two centuries ago, prior to settlement. The

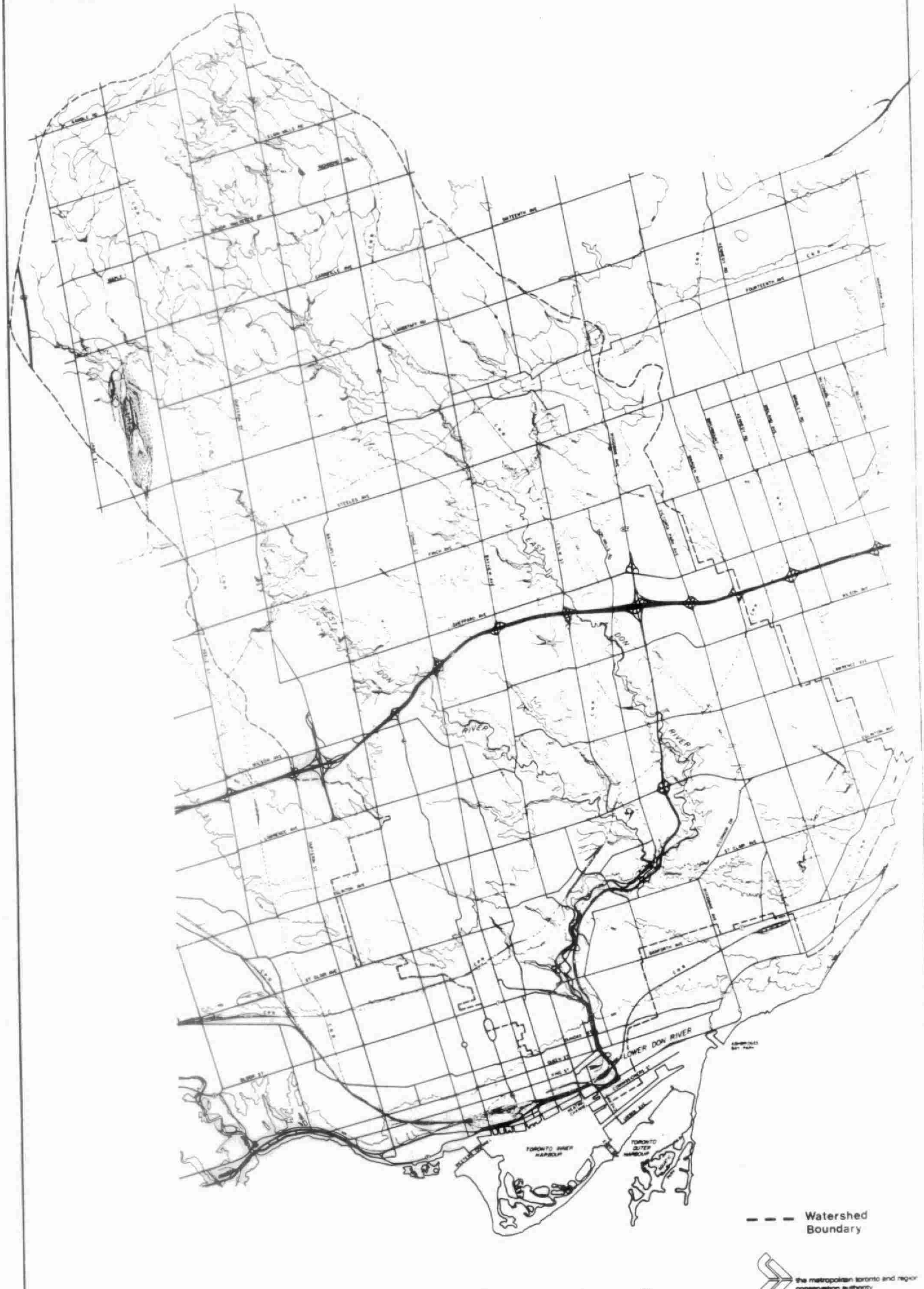

Figure 1. Don River Watershed

basic 360 km^2 watershed area has not changed notably but, with the exception of soils and bedrock geology, the physical and chemical characteristics of the basin have been dramatically altered.

2.2 The Historical Watershed

Table 1 details chronologically the settlement and aquatic conditions in the watershed.

Prior to settlement, it is inferred from surveyor's field notes and the number of sawmills which flourished with settlement that the watershed was almost entirely forested. This would be consistent with findings in nearby watersheds (Smith 1973; ODPD 1956). The heavy forest cover would provide extensive shading of the river and erosion protection of the clay soils. At this time the Atlantic salmon were known to migrate up the river to spawn although no documentation of spawning activity or locations was found.

Once the land surveys were complete settlement progressed rapidly. The early settler regarded the forest as an obstacle to cultivation and set about clearing extensive areas of land. Land clearing, which reduced the ability of the land to retain water, brought about an increase of floods in the watershed. By 1829 remarkable floods in the Don River were becoming a frequent occurrence. Conversely, in 1832 the mill on German Mills Creek closed - attributed to having been placed on a tributary with low flow, yet in 1794 rafts conveyed settlers up this creek. This suggests corresponding baseflow reductions.

Cleared lands now exposed the clay soils to the erosive forces of surface runoff increasing the silt load to the river. Both in 1801 and 1804 failure of the salmon fishing in the Don River was reported. The Indians were unable to spear fish in the spring of those years because the river was so muddied by the 'great floods' (spring freshet) that they could not see the fish (ODPD

TABLE 1. Chronological account of settlement, water resources, fish, urbanization in the Don River watershed, 1787 to 1981.

Year	Comment	Source
1787	Toronto purchase	ODPD 1950
1788	Surveying begins; Don River watershed is now Crown property and ready for settlement	ODPD 1950
1793	First settlement lots are available	ODPD 1950
1794-95	First two water-powered mills (dams) built; Don Mills at Todmorden and German Mills on German Mills Creek.	ODPD 1950
	Rafts convey settlers up German Mills Creek	Sauriol 1981
1798	Fine salmon fishing in Don River; farm for sale near Thornhill advertised salmon fishing in the river 'enough to support a number of families'.	ODPD 1950
1798	Mrs. Simcoe attended an evening of salmon fishing at the mouth of the Don and watched muskie and pickerel being taken through holes in the ice.	ODPD 1950
1800	3 water-powered mills on river	ODPD 1950
1801 1804	Salmon fishing a failure because Indians unable to spear fish that spring as the river was so muddied by the 'great floods' (spring freshet) that they could not see the fish.	ODPD 1950
1821	"River inhabited by various kinds of fish, large quantities of suckers in the early spring and in the latter part of the summer some of the finest salmon which were taken in great numbers sometimes weighing 25 lbs each."	Sauriol 1981
1825	25 water-powered mills	
1829,1833, 1835	remarkable floods begin to be more frequent	ODPD 1950 Acres 1983
1832	German Mills on German Mills Creek abandoned probably because it was placed on a small stream with low flow.	ODPD 1950
ca. 1840	Scadding found the salmon plentiful. "Good fishing of other kinds beside the salmon were numerous, black bass, rock bass, perch, pike. Spring water rivulets entering the main stream at several points were frequented by speckled (brook) trout."	Sauriol 1981

Table 1 continued

Year	Comment	Source
1847	Don River considered as a source of drinking water.	Sauriol 1981
1850	"By 1850 the process of settlement in the Don was drawing to a close except in the broken country east and south of York Mills. Here the proportion of woodland was still remarkable for more than a generation. Settlement in the watershed cannot be said to be completed until after the railways had been running for some time, but in 1850 the area was well settled and prosperous and the frontier had moved far beyond it". Steam power brought into service.	ODPD 1950
1852	Resident near the mouth saw his last salmon. 39 mills in the watershed but no indication of how many were still water-powered	Sauriol 1981 ODPD 1950
1866	Pike and bass spawning in the Don River	Kerr and Kerr V2 May 5
1867	Found 5 pike nets set at the mouth of the Don River.	Kerr and Kerr V3 April 12
1868	Kerr diary refers to rivers in his district which includes the Don. Salmon spawning noted in other rivers but not the Don. He advises that streams need to be kept free from sawdust and mill rubbish to protect the salmon but the Don is not included in his list of those streams.	Kerr and Kerr V4 Sept. 7 & Nov. 17.
1874	Last salmon speared with a pitch fork at Taylors Mill near Pottery Road.	Sauriol 1981
1878	Some water-powered mills were disappearing and lumbering had become small scale Largest magnitude flood to date witnessed; removed 30 dams and 20 bridges	ODPD 1950
1883	Course of the Don to be altered; a new channel to be dredged through the marsh.	Kerr and Kerr V10 Aug. 14
1898	Salmon last found in Lake Ontario	Parsons 1973
1900	Less than 10% of the watershed remains forested.	Acres 1983
1929	North Toronto Sewage Treatment Plant opened	
1930	German Mills (Richmond Hill) Creek is spring-fed; no pollution; no spawning grounds; no trout caught in this creek for several years	Dept. of Game & Fisheries June 4.

Table 1 continued

Year	Comment	Source
1930 1934	Massey (Taylor) Creek evaluated as fair for brown trout at its mouth; 2 STPs discharge into lower portion but effluent considered excellent.	Dept. of Game and Fisheries Oct 4, 1930 Sept. 7, 1934
1939	6 municipal STPs operating; outflow from plants equal in volume to the normal summer flow of the river.	ODPD 1950
1949	The flow of sewage at times was twice that of the river itself. North Toronto Plant efficient with primary and secondary treatment but loaded to capacity. Other plants are also overloaded and result in discharge of effluents of low quality.	ODPD 1950
ca. 1950	Sauriol notes that the effluent from the North Toronto Plant is actually considerably purer than the river water with which it mixes and has the effect to clarify it. "Silver (Taylor/Massey) Creek - silver at its source smells nauseating as it pours its fetid, effluent laden waters into those of the East Don".	Sauriol 1981
1929-1981	31 STPs operated on the Don over these years.	Chin et al. 1981
1957-1962	22 STPs removed from service.	Chin et al. 1981
1963-1981	5 STPs discontinued.	Chin et al. 1981
1981	3 of the 4 remaining STPs removed from service and their flows redirected to the York-Durham system.	Chin et al. 1981

1950). The silt contribution is expected to have reduced the spawning success of the salmon and trout. As well, the reduction in riparian vegetation probably warmed reaches of the river beyond the tolerance or preference limits of the salmon and trout. There is no evidence however, documenting either of these occurrences.

Concomitant with clearing came the building of dams for water-powered saw and grist mills. The first two were built as early as 1794 - one at Todmorden, approximately 6 km from the mouth, and one on German Mills Creek in the headwaters. By 1825 25 water-powered mills were built in the watershed. By comparison, in 1825 there were only 8 dams in the Credit River watershed (ODPD 1956). Not only did the dams prevent migration of fish, particularly the salmon, to spawning beds but they provided a convenient place to capture fish unable to proceed further.

By 1850 the settlement of the watershed was almost complete and environmental deterioration of the river was too far advanced to enable restoration of the salmon stocks. One resident near the river mouth observed his last salmon in 1852 although an alternate report noted that the last salmon in the Don was speared in 1874 at Taylor's Mill near Pottery Road (Sauriol 1981). When the fisheries overseer John Kerr was appointed in 1860, his diary entries at that time made no mention of salmon in the Don River and he did not include the Don in his listing of salmon streams (Kerr and Kerr 1860-1895). By that time however, mitigative and restorative measures were already being undertaken in nearby watersheds in an attempt to improve the rapidly declining salmon stocks. The impacts of settlement were felt earlier in the Don River than in other watersheds which developed somewhat later as the settlement frontier moved from Toronto to the east and west.

Despite rehabilitation efforts, the last indigenous salmon were seen in

Lake Ontario in 1898 (Parsons 1973). No one single cause can be attributed to their decline, but the factors described above apparently worked synergistically to extirpate the salmon from the Don River watershed and eventually the Lake Ontario drainage (Huntsman 1944; Parsons 1973).

2.3 The Industrial and Urban Watershed

With the reduction in forest cover evident by the mid-1800s, the lumber trade began to falter and some mills closed down. Some water-powered mills also closed with the advent of steam power in the 1870s. With industrialization came the tendancy to concentrate industry in larger plants within major centres. Centres of industry attract population (and vice versa) and so the process of urbanization began in Toronto. Soon point source discharges of effluents became an increasing concern rather than the ubiqituous and insidious effects of agricultural land use on aquatic systems. As early as 1929 the North Toronto Sewage Treatment Plant (STP) opened, discharging effluent to the lower Don. Two other plants were in operation in 1930 and discharged to Taylor Creek. By 1939 there were six STPs in operation and it was said that the outflow from the plants was often equal to the normal summer flow of the river (OPDP 1950).

In 1945 a new era of growth began with the post-war years. Population increased rapidly and more agricultural lands became urban. In 1949 the Don watershed was 15% urbanized (ODPD 1950; Table 2), 20% in 1950 and 33% in 1956 (Acres 1983). With this shift to urban land use came the need to build or upgrade sewage treatment facilities capable of servicing the growing population and industrial base. The North Toronto STP was described in 1949 as efficient with primary and secondary treatment facilities but loaded to capacity. Sauriol (1981) remarked that the effluent from the North Toronto STP around 1950 was actually cleaner than the river water. Other plants were

Table 2. Change in urban land use between fish survey years in the Don River watershed.

Year	Percent Urban	Source
1949	15	ODPD 1950
1950	20	Acres 1983
1956	33	Acres 1983
1971	64	Acres 1983
1983	70	Acres 1983
Future	75	Acres 1983

also loaded to capacity and resulted in the discharge of low quality effluents. ODPD (1950) suggested that in 1949 the flow of sewage was at times twice that of the river. Chin et al. (1981) reported that 22 STPs which discharged to the Don were removed between 1957 and 1962 under the Ontario Water Resources Act. Most of the remaining plants underwent technological improvements to improve the quality of the effluent but they were eventually closed in favour of a larger system. Two STPs remain in operation today - the North Toronto Plant and a small plant servicing the Ministry of Natural Resources offices in Maple.

Chin et al. (1981) described some of the legislative and remedial measures which affected the quality and amount of effluent entering the river. They also noted that, with plant closures, increasing urbanization and the technological advances to sewage treatment to include phosphorus removal, water quality has changed in the river.

Routine monitoring data collected since 1965 by the Ontario Water Resources Commission, later to become the Ontario Ministry of the Environment, have been investigated for trends in several water quality parameters (Chin et al. 1981). Between 1965 and 1979 total phosphorus, filtered reactive phosphorus and biochemical oxygen demand (BOD) concentrations at the river mouth have significantly improved ($p=.05$). Conversely, chloride levels have significantly increased since 1965 at the same location. While phosphorus and BOD concentrations have decreased in response to sewage treatment plant improvements (4 STPs still remained at the time of this analysis), abatement of phosphorus use in detergents and closure of some STPs, the increasing chloride concentrations, largely associated with the deicing compounds used on city streets, reflect the increased storm water contributions to the water course.

While the initial TAWMS study used traditional limnological parameters to describe the water quality conditions in the Don, increasing attention was directed at the identification and locations of trace organic and inorganic compounds of concern. Briefly, the water quality review of the initial study found total phosphorus, un-ionized ammonia and copper concentrations frequently exceeded guidelines during either baseflow or storm events. During a wet event, suspended solids, zinc, cadmium, lead, PCBs, DDE, Thiodan, Endrin, Dieldrin, 2,4 -D and PCP were also found to exceed the guidelines. Other trace contaminants were found but no objective or guideline has been established to compare the results with. The TAWMS group indentified instream erosion, stormwater runoff, combined sewer overflows and sewage treatment plant effluents as possible sources of water quality impairment in the Don River watershed which required further investigation (OMOE 1983).

As a final characterization of the study area mention must be made of the role of storm water in the flooding of the watershed. With 70% urbanization, a substantial proportion of the watershed is now impervious to water and consequently precipitation and meltwaters are not absorbed for gradual release. Instead they are conveyed rapidly to the receiving waters through pipes or channelized water courses with the result being rapidly rising waters with a higher peak but of shorter duration (Acres 1983; Mather 1981). Concomitant with flood flows are channel scouring, channel erosion, bank destabilization and transport of large quantities of sediment to depositional zones, in this case the lower Don River and Keating Channel (Acres 1983; Dickinson and Wall 1977; Mather 1981). During the rapid urbanization of the watershed between the 1950s and early 1970s sediment volumes in the Keating Channel were much higher than in the 1940s. A steady decline was observed from the mid 1970s to 1980 (Acres 1983; Mather 1981) with the slowed development. Peak years of sediment deposition appear to have been 1959-1961

and considerable fluctuation was observed in the 1960s and 1970s.

Presently, during large storm events overflow weirs permit the direct discharge of combined storm and sanitary sewage into some sections of the river. Efforts are being made by individual municipalities to separate the combined sewers.

In newer developments, particularly in the upper watershed, control structures designed to detain stormwater for sedimentation and slow release are now included in subdivision plans. Only one major flood control structure, the G. Ross Lord Dam, has been constructed in the watershed (completed 1973) although several others were planned at one time.

3.0 METHODS

Of the 113 stations surveyed by the Ontario Department of Planning and Development, 45 were chosen to be re-surveyed in 1984. These sites were selected to (1) give as complete coverage of the watershed as possible, (2) be representative of a stretch of stream, and (3) inventory sites where sensitive fish species, particularly brook trout and redside dace, were previously known to occur.

In the 1949 survey the river was sampled using a 6 foot long seine hauled through a variety of habitats. A Smith-Root VII backpack (D.C.) electrofisher was used to sample the river in the 1984 survey. Strict comparability with the 1949 results was sacrificed in favour of a more thorough inventory using state-of-the-art sampling equipment. A minimum 25 metre stretch of river was swept once with the electrofisher and fishing was continued until all habitats at that site had been sampled and until no new species were being caught. Fish were dipnetted, retained in a bucket, field identified, counted and released. Where field identification proved difficult, specimens were preserved in 10% formalin and identified using Hubbs and Lagler (1958) and Scott and Crossman (1973). Some specimens were verified by Mr. E. Holm of the Department of Ichthyology and Herpetology, Royal Ontario Museum (ROM).

The 1949 fish survey was conducted in May while the 1984 survey took place between July 3 and July 26. The 1984 survey was planned for July, normally a hot, low precipitation month, to census "worst case" conditions of high water temperatures and base flows. Unfortunately July was unusually wet and cool and consequently the river conditions probably did not represent baseflow or the worst temperature regime.

At each site air and water temperatures were taken and the physical characteristics of each site were recorded on MNR field survey forms.

The 1984 Steedman survey, used to supplement this study, also sampled the fish in a manner similar to this survey. They used a Smith-Root Model 12 backpack (D.C.) electrofisher to sweep a variety of habitats usually within a 100 m stretch. Unfortunately, they only recorded seconds electrofished as an indication of sampling effort so comparison of numbers between the 1984 surveys is difficult.

Fish species scientific and common names are assigned according to Robins et al. (1980). On the tables each species is designated by a code as per Dodge et al. (1980). A complete species listing with the codes can be found on Table 3.

Benthos were sampled once during the month of May in the 1949 survey. Invertebrates were collected in a hand seive or by picking with forceps from aquatic vegetation, wood, stones etc.. Invertebrates were sampled from still, rapid and evenly flowing water and collections were kept separate (Hallam 1959). In this analysis samples for each site have been combined for a total species list and number of individuals.

Two benthos samples were taken in the 1984 survey. The first was done between May 2 and June 11 and the second taken at the time of the fish survey - July 3-26. At each site two samples were taken; one in the riffle area or fast water if no riffle was present, and one in pools or depositional zones. Several substrates within the fast water were kick sampled holding a fine-mesh D-net downstream. A variety of micro-habitats in the depositional zones were swept with the D-net, including overhanging vegetation. Care was taken to exert similar effort between sites and roughly the same total volume of sample was collected. Riffle and pool samples were stored separately in whirl packs, preserved immediately with Kahle's Solution and returned to the lab for picking. Crayfish were most often collected by electrofishing and only a couple of individuals were kept for identification therefore relative

TABLE 3. Scientific and common names for fish species found in all surveys following Robins et al. (1980) and Ministry of Natural Resources species codes used as per Dodge et al. (1981).

Scientific name	Common Name	MNR Code
Alosa pseudoharengus	alewife	61
Salvelinus fontinalis	brook trout	80
Catostomus commersoni	common white sucker	163
Carassius auratus	goldfish	181
Phoxinus eos	northern redbelly dace	182
Clinostomus elongatus	redside dace	184
Notropis atherinoides	emerald shiner	196
Notropis cornutus	common shiner	198
Notropis heterolepis	blacknose shiner	200
Notropis hudsonius	spottail shiner	201
Pimephales notatus	bluntnose minnow	208
Pimephales promelas	fathead minnow	209
Rhinichthys atratulus	blacknose dace	210
Rhinichthys cataractae	longnose dace	211
Semotilus atromaculatus	creek chub	212
Ictalurus nebulosus	brown bullhead	233
Culaea inconstans	brook stickleback	281
Lepomis gibbosus	pumpkinseed	313
Micropterus salmoides	largemouth bass	317
Perca flavescens	yellow perch	331
Etheostoma caeruleum	rainbow darter	337
Etheostoma nigrum	johnny darter	341
Cottus bairdi	mottled sculpin	381

abundance is usually not accurately represented. Each sample was picked a maximum of one-half hour. In some cases this exhaustively picked the sample but in others took the majority of the organisms. Most frequently left unpicked were small oligochaetes and chironomids. Most specimens were identified to species. Only dipterans and coleopterans were left at family and oligochaetes and leeches were left at class. The taxonomic references are listed after the main text references.

Both the benthos and fish data forms have been copied and are on file with Metropolitan Toronto and Region Conservation Authority, Ontario Ministry of the Environment, Water Resources Branch, Ontario Ministry of Natural Resources, Fisheries Branch and the author.

Benthos data have been analyzed in two ways. At each site the Jaccard Similarity Coefficient (Hendricks et al. 1980),

$$(S_j = a / a + b + c)$$

where a = the number of species common to both years
b = the number of species unique to 1949
c = the number of species unique to 1984,

was calculated to determine the similarity of the 1949 total sample with the 1984 total sample. Sampling methodologies were thought to be similar enough to use this index.

The May 1949 sample was compared with the May 1984 sample. This yielded a higher similarity than the May 1949 sample compared with the May and July 1984 samples combined. However, where the May 1949 survey indicated the presence of a species which was noted only in the July 1984 sample this was also included in catagory a. Only like levels of taxa were compared i.e. Baetis brunneicolor was not compared with Baetis spp., but Baetis spp. was compared with all Baetis species listed and given one similarity point.

Also for each site the Biotic Index as proposed by Hilsenhoff (1977) was

calculated to indicate water quality conditions:

$$BI = n_i a_i / N$$

where n_i = the number of specimens of type i
a_i = the pollution tolerance value for type i
N = the total number of individuals

Where pollution tolerance values (a) for species or at the family level were not given by Hilsenhoff, best estimates were made by averaging the values given for other genera and species in that family. Pollution tolerance values for the species found in the Don River have been included in Appendix 1. Hilsenhoff's water quality determinations from the biotic index are shown on Table 7. Where no value could be assumed then that species was dropped from the calculation. The number of specimens in each taxa was standardized to 100 and expressed as a percentage. If the sample had fewer than 25 individuals a poor rating was assigned regardless of the calculated rating. Riffle and pool samples were combined but separate BI's were calculated for the May and July samples.

4.0 RESULTS

4.1 Introduction

Some cautionary notes must preface the interpretation of the results to follow which are largely the product of the sampling technique employed. Additionally, most represent one, or perhaps two, sample collections to establish local presence. Whether this subset of the community accurately represents the structure at a site will depend principally on three factors: (1) the purpose for which the data were collected, (2) the range of habitats sampled, and (3) the sampling gear used (Fausch et al. 1984).

None of the surveys reviewed were undertaken in an exhaustive manner. Nor were attempts made to compare the results obtained with those from an exhaustive survey of the same area.

Of the aforementioned factors, the three main fish surveys had similar intents and sought to inventory a wide range of habitats present at each site. The two surveys differed in sampling gear and a brief mention will be made with regard to the selectivity of seine nets and electrofishers.

The major drawback to seining in a stream environment is its physical characteristics - notably logs, rocks, bottom snags, undercut banks and current. Fish which are characteristically found under cover or in rapid waters are often under-represented in a seine sample unless special techniques or efforts are employed (such as frightening fish out of these areas) to improve the sampling efficiency. Seines are generally selective for small, slow-moving and schooling fishes (e.g. minnows) whose normal habitat is shallow water with few obstructions (Hayes 1983).

Backpack electrofishers, while surrmounting the restrictions imposed by seines on the types of habitats which can be sampled, are affected by other characteristics of the stream. Such factors include: (1) high water

temperatures which increase fish metabolism resulting in an increased ability to perceive and escape the electric field, or cause fish to move into deeper waters or ponds where they cannot be captured, (2) low water transparency which reduces the ability of the dipnetter to capture stunned fish, (3) substrates of fine particles and organic debris are more conductive than coarse bottoms and thus in reducing the density of the electric field, lower the collection efficiency, and (4) morphometry of the water body; fish are less vulnerable to capture in waters with large surface areas perhaps because the electric field is so small relative to the area to be covered and less cover is available. Cover has a concentrating effect on fish and it is the ability of the electrofisher to access these areas that is its major asset (Reynolds 1983).

Electrofishers tend to be size selective as total body voltage increases with length resulting in a greater shock. Larger, silvery or brightly coloured fish tend to be collected first as they are more visible to the dipnetter. Conversely, schooling fish tend to avoid capture, perhaps because of small size and/or a group fright response. Benthic fishes, although readily shocked, if not captured on the initial draw to the anode, may be lost in the substrate and under-represented (Larimore 1961; Mahon 1980; Reynolds 1983; Wiley and Tsai 1983).

In conclusion, surveys which used only seines are expected to adequately represent most cyprinids, fishes of still and shallow waters such as percids, centrarchids, white suckers, sticklebacks and the juveniles of some of the more elusive species such as trout and hog suckers. Larger specimens and benthic species are expected to be under-represented.

Electrofishing may not adequately census the cyprinid species present and will probably under-estimate population numbers of these and other schooling fishes such as yellow perch. Benthic and fast swimming species may pose

problems but these can be surrmounted by careful attention to sampling strategy.

Biologists rely strongly on the presence of species, particularly those for which environmental requirements have been determined as they are useful indicators of aquatic conditions. Although tolerant species can be found in both clean and polluted waters, the presence of only tolerant species, supported by a lack of intolerant species reinforces the conclusion regarding prevailing water quality conditions.

Utilization of fish or benthos data alone may not be adequate to accurately depict aquatic conditions. For example, benthic organisms are largely sessile and consequently would reflect more accurately the conditions at that site than fish which are highly mobile and may exhibit avoidance reactions to short-term stresses. However, the timing of a benthic sample is particularly critical as most species have rather involved but limited life cycles. Sampling time is not as critical with fish unless migratory species are sought or there is a need to determine whether spawning is occurring at that site. Such investigations would almost need to be species specific. Benthic organisms usually have a one year life cycle and would be rapidly eliminated from a river section if environmental conditions were unsuitable (Cairns 1974). Conversely, fish usually live two years or longer and may be only gradually eliminated through continued reproductive failure of the spawning population present there. Fish have fewer microhabitats than benthos and are probably better represented by one site visit than the invertebrates. Between sampling technique, field and laboratory sorting procedures, life histories, spatial heterogeneity and environmental conditions prior to sampling which may have killed or initiated the drift of many organisms (Resh 1979), there is a good chance of missing or under-representing some

invertebrate species. Consequently, although the main discussion centers on fish, the final analysis relys strongly on the combination of fish and benthos data to characterize the Don River.

The following discussion briefly outlines the individual surveys reviewed and their unique or common elements. Subsequently, distributional shifts by species on a watershed basis are examined prior to a detailed station-by-station comparison. General features of the two benthic surveys are discussed but a detailed analysis of the community on a station-by-station basis has not been done largely because of the difficulties inherent in handling the number of species identified and the lack of similarity of species found in the two surveys.

4.2 Individual Surveys

4.2.1 1949 Ontario Department of Planning and Development

The Ontario Department of Planning and Development undertook biological inventories of southern Ontario watersheds during the late 1940s and 1950s in an effort to provide a natural resources data base for the formation of the Conservation Authorities.

One hundred and thirteen sites were examined in 1949 throughout the Don River watershed which yielded very extensive coverage. Fish and benthos surveys were undertaken at 89 of these sites. The remainder were dry or not found. A data summary is presented in Appendix 2.

Species unique to this survey included the alewife, brook trout, blacknose shiner and brown bullhead.

Blacknose dace were the most commonly found species followed closely by the creek chub. White sucker, common shiner and johnny darter were also commonly distributed, occurring at roughly 50% of the sites surveyed.

4.2.2 1984 Survey

From the original 1949 survey sites, 45 stations were chosen to be inventoried in 1984 with the intent to document biological conditions 35 years later and to provide an up-to-date data base from which to evaluate proposed watershed improvements. Both fish and benthos were sampled at all sites. A data summary can be found in Appendix 3.

Species unique to this survey were goldfish, emerald shiners, spottail shiners and yellow perch. The shiners were found only in the lower reaches and represent elements of the Lake Ontario fauna. Perch may have been introduced from ponds and goldfish liberated via the sewer system so these are not considered range extensions.

The most common species was the creek chub followed closely by the blacknose dace, a reversal of the 1949 situation. White sucker and longnose dace also were abundant, found at approximately 45% of the sites surveyed. These four species are considered pollution tolerant and in this river represent the majority of the fish community.

4.2.3 1984 Steedman Survey

Fish data have also been used that were collected by Steedman of the University of Toronto as part of a larger survey of urbanized watersheds. He inventoried fish at 26 sites, 18 of which duplicated the sites of this study. His results have been used together with the other 1984 data and to supplement this study where different sites were sampled but had a corresponding 1949 location (Appendix 4).

The only species unique to this survey was largemouth bass, at one site, probably introduced from a pond.

The creek chub was the most common species in this survey also and was followed by blacknose dace and white sucker which were equally distributed.

Longnose dace were also common and pumpkinseed were found to be much more abundant than in the other surveys. Perhaps they have been washed out of local ponds.

4.2.4 Other Inventories

The results of a few scattered fish inventories were reviewed. They have not been included in the detailed analysis because of the limited watershed coverage, wide variety of sampling times and techniques and lack of coinciding sites.

Generally there is good agreement between these survey results and those of the 1984 inventory, although a few discrepancies were found. Limnos Ltd. collected minnows in 1982 with a beach seine and minnow traps for the trace contaminants in young-of-the-year fish program of the TAWMS study. Longnose dace were collected for analysis and this bias is reflected by the presence of longnose dace at roughly 60% of the sites examined while creek chub and blacknose dace, usually the most commonly found species, were virtually absent. This survey also found common shiners to be much more abundantly distributed in 1982 (at approximately 41% of the sites) than found in the 1984 survey (13%). Limnos also found blacknose shiner at one site below the G. Ross Lord Dam on the West Don River. This was the only record since 1949 but it is not verified.

Metropolitan Toronto and Region Conservation Authority has conducted limited sampling between 1981 and 1984 around flood damage centres using a combination of seines and electrofishing. They found hog suckers (Hypentilium nigricans) and the brassy minnow (Hybognathus hankinsoni) which are a first record among the surveys reviewed. The brassy minnow was found near the mouth of the Don and may be more an element of the Lake Ontario fauna. Both species would be considered rare in this watershed.

A third survey was conducted by Martin in October 1981. Twenty sites were sampled for fish and benthos. Fish were collected by seine and dipnet and a D-frame net was used to collect invertebrates kick sampled in riffle areas. He found two species previously unrecorded in the watershed - pearl dace (Semotilus margarita) and smallmouth bass (Micropterus salmoides). The pearl dace was found near the mouth of the river and is more commonly associated with lakes than streams. The smallmouth bass may have been misidentified. Largemouth bass are known to exist in the pond and adjacent sections of stream (near 1F3) at this site (Martin, field observations 1983; Steedman 1984).

Martin's survey found creek chub to be the most commonly distributed (45% of the sites) and common white sucker the next most common, at 25% of the sites sampled.

4.3 Distributional changes overview

Prior to an in-depth station-by-station analysis, it is instructive to take a preliminary look at the relative occurrence by species in the watershed. This provides an initial flagging of species which may have changed distributions through time or are sensitive to sampling technique. Table 4 presents the number of stations that each fish species occurs at by year, the number of sites that each species occurred at expressed as a percentage of the total number of sites inventoried, and the number of sites that each species occurred at expressed as a percentage of the number of sites where fish were found.

It is interesting to note that in both the 1949 and 1984 surveys, 15% of the sites had no fish, although not all of the sites coincided. The 1984 survey of Steedman had only 8% of the sites without fish but they did not direct sampling efforts at the smaller urban tributaries.

TABLE 4. Watershed-wide occurrence of each fish species in 1949 compared with 1984 showing a) the actual number of stations per species, b) the percentage of all stations, and c) the percentage of stations with fish

Year	Species Code 61	80	163	181	182	184	196	198	200	201	208	209	210	211	212	233	281	313	317	331	337	341	381	# Stations
No. Stations/species																								
1949	1	2	38	—	23	22	—	37	2	—	17	30	62	23	56	1	6	1	—	—	20	39	3	85
1984	—	—	27	2	10	2	1	5	—	1	3	6	30	17	31	—	2	3	—	1	1	10	3	45
1984S[a]	—	—	17	1	7	1	—	2	—	—	4	4	17	10	20	—	—	8	1	1	—	7	2	26
Percentage/species using all stations																								
1949	1.2	2.4	44.7	—	27.1	25.9	—	43.5	2.4	—	20.0	35.3	72.9	27.1	65.9	1.2	7.1	1.2	—	—	23.5	45.9	3.5	85
1984	—	—	60.0	4.0	22.0	4.0	2.0	11.0	—	2.0	7.0	13.0	67.0	38.0	69.0	—	4.0	7.0	—	2.0	2.0	22.0	7.0	45
1984S	—	—	65.4	3.8	26.9	3.8	—	7.7	—	—	15.4	15.4	65.4	38.4	76.9	—	—	30.8	3.8	3.8	—	26.9	7.7	26
Percentage/species using only stations with fish																								
1949	1.4	2.8	52.8	—	31.9	30.6	—	51.4	2.8	—	23.6	41.7	86.1	31.9	77.8	1.4	8.3	1.4	—	—	27.8	54.2	4.2	72
1984	—	—	71.0	5.0	26.0	5.0	3.0	13.0	—	3.0	8.0	16.0	79.0	45.0	82.0	—	5.0	8.0	—	3.0	3.0	26.0	8.0	38
1984S	—	—	70.8	4.2	29.2	4.2	—	8.3	—	—	16.7	16.7	70.8	41.7	83.3	—	—	33.3	4.2	4.2	—	29.2	8.3	24

a 1984S Survey done by R. Steedman, University of Toronto.

Several species have experienced striking reductions in distributions over 35 years. Although not abundant in 1949, brook trout are now not found in the watershed despite concentrated efforts to locate them. Brook trout are most often found in cool, clear, spring-fed waters and prefer spring-fed gravel beds for spawning (Scott and Crossman 1973). As inhabitants of cold water they are intolerant of elevated water temperatures preferring temperatures of less than 20°C (Houston 1982; Scott and Crossman 1973). Additionally, their habitat, usually cold, running waters, tends to be well oxygenated. Consequently the brook trout tends to use oxygen liberally and requires higher concentrations than species which inhabit still waters (e.g. centrarchids and percids).

Spring-fed waters are commonly associated with regions of coarse textured soils which allow deep seepage of precipitation and melt waters. Additionally, coarse soils contribute very little silt and provide an abundance of gravel instream. The small area of coarse soils in the headwaters of the Don watershed suggest that trout distribution would have been largely restricted to this area prior to development. Headwater housing developments now contribute storm water, sediment from construction and may alter groundwater flows.

Redside dace were once widely distributed at 22 (30.6%) of the sites. In total, they could only be located at 3 sites (7.7%) in 1984 despite sampling 20 of the 22 sites where they were previously found. The redside dace is reported to prefer cool, clear waters with gravelly or stoney bottoms and to be sensitive to domestic, industrial and agricultural pollution (McAllister 1983; McKee and Parker 1982; Scott and Crossman 1973). Although this species has been found, in this and other studies, in habitats somewhat contrary to that described above, the dramatic decline in their distributions must reflect

a sensitivity particularly to urbanization as agricultural influences were prevalent in the watershed long before the 1949 survey. The urban waters may have become warmer still and further riparian vegetation removal may decrease the amount of terrestrial insects available as food. Scott and Crossman (1973) note that up to 75% of their diet may be terrestrial or adult forms of aquatic insects.

Common shiners were among the most widely distributed species in 1949, found at approximately 51% of the sites. In 1984 they were only located at 13% of the sites. Selectivity of the sampling gear is not likely to account for this change as their silvery appearance facilitates their capture by electrofishing. Aside from individual physiological tolerances (for which data are not readily available) there is no obvious ecological reason why common shiners should have dramatically reduced distributions in the Don River while the creek chub, with almost identical ecological requirements, remains widely distributed. Both species are late spring spawners, omnivorous, and spawn in gravel beds in flowing water - in fact common shiners frequently utilize creek chub nests for spawning. The chub is described as being a hardy fish with regard to being kept for bait while the shiner, also a common bait fish, is described as sensitive to prolonged confinement in a bait bucket (Scott and Crossman 1973) suggesting considerable physiological differences between the species. Range reductions attributed to turbidity resulting from agricultural practices have also been noted for the shiner (Scott and Crossman 1973).

Blacknose shiners were only found at 2 sites in 1949 and could not be located in either 1984 survey although they were noted at one station in the small 1982 Limnos survey. Blacknose shiners inhabit quiet weedy bays and streams with shallow water over sand and gravel bottoms. Although it is possible that this fish is more difficult to capture by electrofishing because

of the difficulties with seeing and dip-netting fish in weeds, range reductions have been noted and attributed to the disappearance of clear vegetated waters (Scott and Crossman 1973). Additionally, eggs are scattered directly over sand. Sand is commonly found in the Don watershed but it is a very unstable substrate and subject to shifting with frequent floods which would bury or wash away the eggs. In 1949 however, these shiners were not common in the watershed.

Both bluntnose and fathead minnows have much reduced distributions in 1984. They are usually collected effectively by electrofishing and probably represent a real reduction. The habitat requirements of the bluntnose and fathead minnows are similar, preferring still waters over a variety of substrates. Both species lay their eggs in nests on the under surface of stones, logs or other debris in shallow water and nests are guarded by the males. In the case of the bluntnose minnow, the presence of the male is described as essential to ensure a continuous supply of water over the eggs and to keep them free of silt. If the male is removed the eggs will die within 12 hours (Scott and Crossman 1973). While their spawning habitat would be prone to silt accumulation, the nest guarding should alleviate this to some extent. Perhaps a more important factor in their reduction would be the frequent flooding of the Don which scours substrate burying nests or removing fish.

Blacknose dace, longnose dace, creek chub and white sucker are as abundantly distributed now as they were in 1949. The slight increase in longnose dace in 1984 is probably an artifact of electrofishing efficiency over seining in rapid water, their preferred habitat. Blacknose dace and creek chub were by far the most abundant species in all survey years occurring at approximately 80% of the sites. All four species spawn in the spring over

gravel substrate in running water. Chironomids form the predominant component of their diet with the exception of the creek chub which is omnivorous. The longnose dace and the white sucker are benthic which may enable them to better withstand flood currents yet the rainbow darter, also a benthic species of running water has decreased its distribution.

Gradall and Swenson (1982) noted that creek chub do not appear to be adversely affected by turbidity.

The blacknose dace is described as tolerant of a wide range of environmental conditions and capable of living where no other fish can (Klein 1979). Environmental tolerances for the white sucker and longnose dace have not been explicitly outlined. White suckers exhibited increased tolerance to cadmium with previous metal exposure (Duncan and Klaverkamp 1983) and were more tolerant of elevated zinc, copper and cadmium concentrations than walleye, lake herring or whitefish (McFarlane and Franzin 1978).

The continued presence of these four species, particularly of the juveniles, suggests implicitly a greater tolerance for variable environmental conditions than other species inhabiting similar reaches as their ecological requirements make these species little different from others which have declined in recent years.

The 1984 Steedman survey found an increased occurrence of pumpkinseed. This is interesting but not entirely explainable. Electrofishing does facilitate the capture of this species but both 1984 surveys electrofished and duplicated 18 sites.

Two other species have greatly reduced distributions - the johnny darter and rainbow darter. Both are benthic in habitat and their capture requires special attention by either sampling technique. The rainbow darter prefers gravel or rubble substrate and is commonly found in riffle areas. The severe reduction from 27.8% to 3% of the sites is likely accounted for by the

increase of silt in the watershed and frequent flooding of these habitats. Scott and Crossman (1973) note that the rainbow darter may be a valuable indicator of pollution for it is extremely sensitive to chemical pollution and silting.

Johnny darters have been reduced from 54 to 26% of the sampling sites but they are still a relatively abundant component of the fauna. Kuehne and Barbour (1983) note that this species is tolerant of a broad range of environmental conditions. However, they do lay their eggs in a manner similar to the fathead and bluntnose minnows and probably have experienced reduced spawning success with the changes in sediment loading since 1949 despite their egg guarding activities to keep them free of silt. Kuehne and Barbour (1983) suggest that local and regional disappearance of this species is probably associated more with siltation than the presence of toxic substances.

Despite these changes in distributions, the number of species in the watershed remained constant at 18 - although not the same composition.

4.4 Station-by-station distributional comparison

Almost without exception the 1949 survey had greater diversity than that observed in the 1984 surveys. This is particularly meaningful as seining is generally regarded as a less efficient method of fish capture usually yielding fewer species and individuals than a sample collected by electrofishing.

The fish data have been grouped into tributaries for ease of discussion. The comparative data are presented by station in Table 5 and although not explicitly divided into tributaries, the data follow the same progression as the discussion. Figure 2 shows station locations.

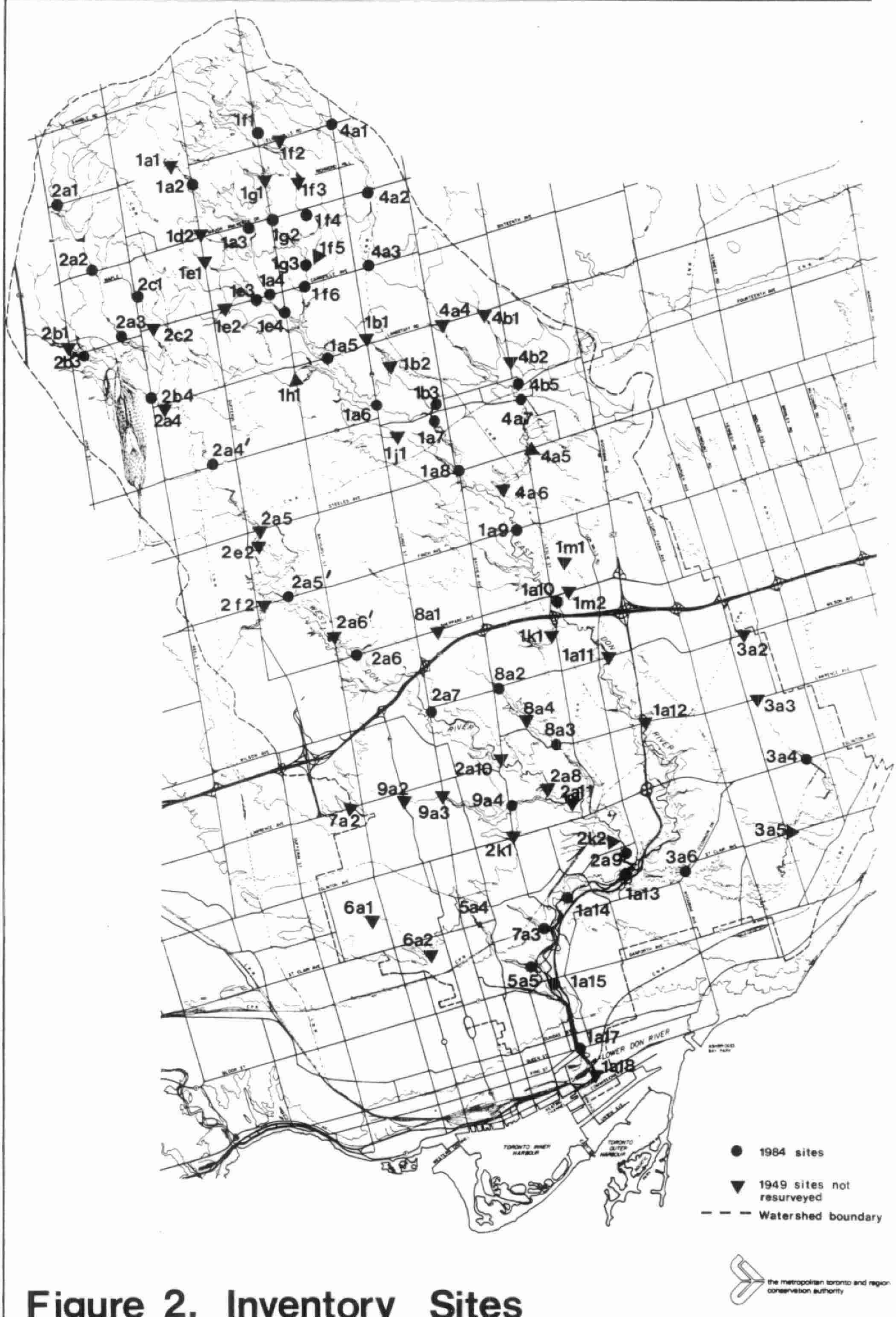

Figure 2. Inventory Sites

TABLE 5. Fish data comparison between 1949 and both 1984 field surveys by station.

Station		61	80	163	181	182	184	196	198	200	201	208	209	210	211	212	233	281	313	317	331	337	341	381	Species	Effort
									Species Code																	
1a2	49		2			1								5										1	4	
	84					87								60											2	25m
	84S					33								41											2	463 s
1a3	49			2		1			1					2		5									5	
	84			14								2		14	3	34					3				6	35m
	84S			31		1						1		12		7					1			1	7	444s
1a4	49					1			3					2	5	6									5	
	84			4		1								11	3	17									5	45m
	84S																								ND	
1a5	49			2			2		2				1	1	3	1						7	3		9	
	84			13										16	85	12							5	7	6	75m
	84S			27					4					40	15	17							1	20	7	543s
1a6	49													3	9	9							3		4	
	84			3										1	6	8									4	60m
	84S																								ND	
1a7	49								2				1	2	4	4						8	5		7	
	84			8										4	16	12							3		5	75m
	84S																								ND	
1a8	49						1		4					3	5	2						12	4		7	
	84			8	1											3							3		4	100m
	84S			7/2											-/1	2/4			1/1						3/4	seine/elect.836s
1a9	49			1			2		3				3	3	3	4		2				4	5		10	
	84			5										7	71	4									4	60m
	84S																								ND	

Table 5 continued

Station	61	80	163	181	182	184	196	198	200	201	208	209	210	211	212	233	281	313	317	331	337	341	381	Species	Effort
							Species Code																		
1a10 49			1					5			1	6	1	3	1						3	5		9	
84			+										4	13	1									4	40m
84S																								ND	
1a11 49								2			1	2									2	4		5	
84																								ND	
84S			7										41	79				1						4	760s
1a12 49			2					5				5	2	1	4						7	5		8	
84																								ND	
84S			44										3	14	7			10						5	915s
1a13 49								3				8	6	8	4						9	4		7	
84			2										1	39	1									4	50m
84S																								ND	
1a14 49																								0	
84			3											36										2	65m
84S																								ND	
1a15 49																								0	
84			11									13	4	48	2		2							6	65m
84S			37									1	32	40	21			2						6	NA
1a17 49	1											1												2	
84			3				10			29														3	3 seine hauls
84S																								ND	
1b3 49			2		1	1		2				6	4	1	4		1					2		10	
84			5		2			2				2	3		38		1	1				1		9	50m
84S																								ND	

Table 5 continued

								Species Code																		
Station		61	80	163	181	182	184	196	198	200	201	208	209	210	211	212	233	281	313	317	331	337	341	381	Species	Effort
1e3	49		1	2		2	4		4				4	3	1	2							1		10	
	84			2		2			1					14	4	18							6		7	50m
	84S			12		10								18		10							5		5	333s
1e4	49			2		4	1		4					3	3	5							4		8	
	84			10					4					12	33	12							3	+	7	50m
	84S																								ND	
1f1	49																							7	1	
	84													2										4	2	50m
	84S			1																					1	387s
1f4	49					2	1		8					4		4							6		6	
	84						2							6		62			2						4	60m
	84S													1	1	34			8	4					5	609s
1f5	49			2					3					4		9	1						9		6	
	84			2										53	18	40									4	60m
	84S																								ND	
1g2	49			2		1	6		1					8		6							7		7	
	84					8								73		61							2		4	60m
	84S					23	17							172	1	125							4		6	521s
1g3	49			2			5		3				1	7		8							4		7	
	84													18	1	25									3	25m
	84S																								ND	
2a1	49			2		1						8		5		3							4		6	
	84			1								27		4											3	25m
	84S			20		1						12		8		11							1		6	568s
2a2	49			2		4	1		6			5		2		3							6		8	
	84			1		1						1		5		6							3		6	35m
	84S			23								47		3		70							14		5	583s
2a3	49					3	4		4			8		2		2							9		7	
	84			4		1	3		3					122		35						1	30		8	30m
	84S																								ND	

Table 5 continued.

Station		61	80	163	181	182	184	196	198	200	201	208	209	210	211	212	233	281	313	317	331	337	341	381	Species	Effort
									Species Code																	
2a4'	49			2		3	2		3	2		4		3		4						2	1		10	
	84			5										3		17									3	130m
	84S																								ND	
2a5	49			3			6		3			4		11		2						1	4		8	
	84																								ND	
	84S			1		2							2	15		6			1						6	889s
2a5'	49			1			1		2			3		4	2	2						6	1		9	
	84			3	5											2									3	110m
	84S																								ND	
2a6	49			4			1		3					1	5	1						2	3		8	
	84												1			4			2						3	75m
	84S												2			3			4						3	695s
2a7	49													4	5										2	
	84			1		1							2			1									4	100m
	84S																								ND	
2a9	49												3	1		2									3	
	84			10												5									2	75m
	84S			11											42	1									3	721s
2a10	49			2					2					4	5							1			5	
	84																								ND	
	84S			36												57									2	601s
2b3	49			1		4			1			1		7		2							2		7	
	84			5		1			2				1	17		43							27		7	180m
	84S			3					2				6	7		27							9		6	642s
2b4	49			2		3	2		4			3		3		1						2	5		9	
	84			1		1								6		7									4	50m
	84S																								ND	

Table 5 continued.

Station		61	80	163	181	182	184	196	198	200	201	208	209	210	211	212	233	281	313	317	331	337	341	381	Species	Effort
								Species Code																		
2c1	49						2					2		7		5							6		5	
	84												1	9		17									3	25m
	84S																								ND	
3a4	49												2												1	
	84																								0	60m
	84S																								0	829s
3a6	49																								0	
	84			10										2	78										3	80m
	84S			2										6	62	1									4	699s
4a1	49			1		1								4		3									4	
	84													27		19									2	50m
	84S													95		38									2	770s
4a2	49			2					2				1	1											4	
	84																								0	100m
	84S																								ND	
4a3	49												1	3		4									3	
	84													1											1	55m
	84S																								ND	
4a4	49			5					1				3	5	2	3							3		7	
	84																								ND	
	84S				1											6									2	714s
4a5	49			1					3			1	1	3	2	2						5	3		9	
	84																								ND	
	84S			19										26	238	20			1						5	770s
4a6	49			2			4		4			5	3	4	3	3						4	3		10	
	84													7	95	4									3	55m
	84S																								ND	

Table 5 continued.

Station		61	80	163	181	182	184	196	198	200	201	208	209	210	211	212	233	281	313	317	331	337	341	381	Species	Effort
		Species Code																								
4a7	49			3			5		3				4			6							3		8	
	84			8										1	1	21									4	80m
	84S																								ND	
4b5	49			1		1	1		1			1	2	1	1	1						1	2		11	
	84															13									1	55m
	84S																								ND	
5a5	49												5	3		2									3	
	84																								0	85m
	84S																								ND	
7a3	49																								0	
	84																								0	55m
	84S																								ND	
8a2	49																								dry	
	84																								0	50m
	84S																								ND	
8a3	49			4										5		2									3	
	84																								0	60m
	84S																								0	789s
9a4	49													1											1	
	84																								0	45m
	84S																								ND	

84S = Steedman survey results
000s = seconds electrofished

ND = no data for that site
NA = not available

4.4.1 Main Don River - headwaters to near the mouth 1A2 - 1A15

Brook trout were only found in the headwaters of the Don in 1949 but they were rare even then. They now appear to be absent as are several other species which may be more sensitive to habitat changes associated with increasing urban development.

Redside dace were not located in 1984 at any of the three sites where they were previously found. Rainbow darters also were not found in 1984 at any of the 8 1949 sampling sites. Similarly johnny darters were not found in 1984 at 6 of 9 sites and common shiners could only be located at 1 of 10 of the 1949 sites. Conversely, we have now witnessed a return of fish to 2 locations on the mainstream which were previously devoid of fish. Two sites, 1A14 and 1A15, immediately downstream of the North Toronto Sewage Treatment Plant (STP) now support a reasonably abundant fish fauna. The mouth station at Queen Street has a completely different fauna between sample years. It was very difficult to sample as it is deep and silty so different methods had to be employed. The 1949 field notes suggested that a gillnet should have been used. A boat was used to draw a seine through the channel in 1984. Its proximity to the mouth accounts for the occurrence of spottail and emerald shiners in 1984 and alewife in 1949, all elements of the Lake Ontario fauna.

Throughout the mainstream, from the headwaters to near the mouth, faunal composition does not stray far from the four dominant species - white sucker, blacknose dace, longnose dace and creek chub. Other species are invariably represented but only by a few individuals.

4.4.2 Headwater tributaries to the Main Don 1B,E,F,G

Within the upper most reaches of these feeder streams some semblance of sensitivity remains in the fauna. At approximately half of the sites common shiners and johnny darters remain but only 2 of 6 sites still have redside

dace. Sculpins, indicative of cold water, were found in a couple of feeder tributaries suggesting that these conditions persist. The greatest species diversity observed in 1984 in the watershed (9 species) was found in this section.

4.4.3 Don River West Branch - Mainstream 2A1 - 2A10

In 1949 the West Branch retained an average diversity of 8 species from its upper reaches to within the upper boundary of Metro Toronto, roughly 15 km of stream to Station 2A6. Today this diversity is only maintained within the upper 5 km of this branch, to 2A3. Downstream of this (2A4' -) several species previously flagged for sensitivity, are no longer found - redside dace, common shiner, blacknose shiner, bluntnose minnow, rainbow darter and johnny darter.

Two sewage treatment plants, which discharged to the West Don between 2A6 and 2A7, reduced diversity in 1949 from 8 to 2 species, respectively. Four species were located at 2A7 in 1984 but all were of low abundance. Station 2A9 was urbanized prior to 1949 and the effect is reflected in low diversity and species abundances in both years.

4.4.4 Taylor (Massey) Creek 3A4, 3A6

The Department of Fish and Game surveyed this stream on two occasions in the 1930s - October 4, 1930 and September 7, 1934 - to assess its suitability for stocking. In 1930 they noted that the source was surrounded by agricultural lands and the stream was stagnant and turbid. The mid-section was turbid and open with some wooded sections but the mouth was well wooded with coarse and fine gravel substrate and clear waters. At this time they mentioned the Scarborough and Woodbine sewage disposal plants were discharging

to the creek and the 1934 survey considered the effluent to be of excellent quality. They recommended that brown trout be stocked in the mouth region as an experiment as cover and pools were suitable.

By 1949 however, the developed - agriculture becoming urban - nature of this stream was reflected by an almost complete lack of fish at station 3A4 and a complete lack of fish in 1984. The two STPs still discharged to this creek upstream of Station 3A6 in 1949 and combined with its urban location resulted in the elimination of the fish fauna. A pollution tolerant but reasonably abundant fauna was found there in 1984, aided no doubt by the closure of the plants.

4.4.5 German Mills Creek - Mainstream 4A1 - 4A7

The Department of Fish and Game also undertook a survey of this stream on June 4, 1930 to assess its suitability for stocking. At that time they noted that the stream was spring-fed all along its course, that it was permanently flowing and had no pollution sources. They found blacknose dace, shiners, redbelly dace and suckers present. They did not advise stocking at that time as they did not find this creek to present suitable conditions for brook trout. They noted that no trout had been caught in the creek for several years and that part of the stream that flows through pasture lands serves as a duck pond, often having a heavy brown scum floating on its surface.

Once following a natural course in its upper waters, this stream is now contained in an underground sewer through the Town of Richmond Hill. The contribution of urban runoff to the stream has resulted in a greatly reduced fauna for roughly 10 km of the stream's (approximately) 13 km length; recovery was not noted until 4A7. The fish species remaining in this stream now consist almost solely of the four most pollution tolerant species - white sucker, blacknose dace, longnose dace and creek chub. As with other sites,

redside dace, common shiner, fathead minnow, bluntnose minnow, rainbow darter and johnny darter now appear to have been eliminated from this tributary watershed.

The 1949 survey was conducted prior to the building of the Richmond Hill STP in 1957. It was closed in 1981 and the stream had recovered from the influence of the effluent prior to the 1984 sample.

4.4.6 Urban tributaries

Many of the tributaries to the Don within the City of Toronto now are contained in sewers underground and are used to aid in the disposal of storm and combined sewer overflows. Several sites were inventoried where these streams are above ground (5A5, 7A3, 8A2, 8A3, 9A4). Some of these still follow natural courses but others have been channelized and stabilized to allow rapid passage of storm waters.

Sauriol (1981) referred to Mud Creek which runs through the north Rosedale ravine. It is assumed that this is the same stream as 5A5. He noted (no date) that it was full of shiners, chub and 'soldier fish so named because of the red stripe along each side' (these fish may have been blacknose dace or redside dace). The 1949 survey still located blacknose dace, chub and fathead minnows at this site but in 1984 not a fish could be found. The Don Valley Parkway development caused the lower end of this stream to be sewered which effectively cuts off its connection with the main river. Additionally the 1984 field survey found sanitary sewage debris and an extreme high water mark indicating flooding and contamination from sanitary sewage. The stream bottom and banks have been stabilized with gabion baskets.

Station 7A3 also receives water from underground sewers and only retains a natural course for a few hundred meters. The Don Valley Brickworks

interrupted its course and connection to the main Don prior to 1949. Consequently no fish were located in either survey.

Two sites on Wilket Creek were examined in 1984 - 8A2 and 8A3. Both sites retain a naturalized course, a good variety of habitat and were extremely cold without apparent explanation. Mainly an agricultural stream in 1949, the upstream site was found to be dry and a pollution tolerant fauna was located at 8A3 in 1949. Fish were not found at either site in 1984.

One blacknose dace was found at Station 9A4 in 1949 reflecting the urban nature and lack of habitat in this stream. In the upstream reaches of this stream no living invertebrate or fish could be located, attributed to a thick "pollution carpet" there. Although not defined, pollution carpet is expected to mean mats of algae and sewage fungus covering the substrate. Further downstream the creek entered a pipe and again no fauna could be found. No fish could be located in 1984.

4.5 Benthic Inventory Results

In a fashion similar to the fish analysis, a number of benthic species characteristic of different water conditions (Appendix 5) were selected from the 1949 and 1984 species lists. For a complete species listing see Appendix 1. Table 6 lists these species mainly in descending order of sensitivity. For each species Hilsenhoff's (1977) pollution tolerance rating is shown (0 = poor tolerance; 5 = very tolerant). These species are then grouped mainly into families or order. For each of these groupings the number of stations where the species or family was found is shown as a percentage of the total number of stations sampled.

These groupings were further reduced into three pollution tolerance assemblages - intolerant, moderately-tolerant and tolerant. Characteristic species are defined in Appendix 5. The fauna for each station was assigned to

TABLE 6. Analysis of select benthos data from 1949 and 1984 surveys showing number of stations where each was present expressed as a percentage of the total number of stations compared.

	% occurrence by station[a]			% occurrence by station[b]			% occurrence by station[c]	
Invertebrate species	1949	1984	Species Grouped	1949	1984	Tolerance Grouping	1949	1984
Plecoptera								
Nemoura 0[d]	4.2	6.4	Plecoptera	15.2	10.9			
Isoperla/ Leutra 0	4.2	2.1						
Ephemeroptera						Intolerant	13.0	0
Paraleptophlebia spp. 1	36.2	6.4						
Habrophlebiodes spp. 1	21.3	2.1	Leptophlebidae	50.0	8.7			
Baetis tricaudata 1	27.1	19.1						
B. brunneicolor 2	25.5	19.1						
B. flavistriga 2	59.6	42.6	Baetidae	67.4	67.4			
B. intercalaris 3	25.5	4.2						
Cloeon spp. 2	10.6	19.1						
Caenis spp. 3	38.3	4.2						
Heptagenia spp. 1	4.2	0						
Stenonema vicarium 1	14.9	6.4	Heptageneidae	45.7	6.5	Moderately-Tolerant	65.2	41.3
S. tripunctatum 3	17.0	2.1						
Tricoptera								
Hydropsyche spp. 3	57.4	48.9	Hydropsychidae	65.2	52.2			
Limnephilidae	8.5	12.8						
Odonata								
Ishnura spp. 4	6.4	12.8						
Boyeria spp. 1	6.4	10.6						
Diptera								
Chironomidae 4	85.1	97.9	Chironomidae	84.8	93.5			
Simulidae 2	59.6	38.3						
Syrphidae *Eristalis 5*	4.2	0						
Amphipoda								
Hyalella azeteca 4	29.8	23.4				Tolerant	21.7	58.7
Isopoda								
Asellus spp. 5	8.5	38.3						
Oligochaeta	14.9	97.9						
Hirudinea	10.6	59.6	Oligochaeta/Hirudinea	21.7	97.8			

a 47 stations compared b, c 46 stations compared d pollution tolerance values as assigned by Hilsenhoff 1977

one of the three groups by examining the percentage composition of the fauna. Where greater than 50% of the organisms fell into the same catagory then that one was assigned.

Jaccard Similarity Coefficients (Appendix 6) calculated between 1949 and 1984 for each station have not been used in these analyses. The results showed very little similarity between years which may have been more the consequence of sampling than environmental conditions.

The Plecoptera species show very little variation between years but were not widely distributed in either year. Both genera of Leptophlebidae and the group as a whole have undergone a considerable loss in distribution since 1949. These species are considered pollution intolerant (Hilsenhoff 1977) and were shown by Hallam (1959) to be frequently associated with the cold water species of brook trout and mottled sculpin in the headwater reaches of rivers.

With the exception of Cloeon spp., all the Baetid species have experienced some reduction in distribution since 1949 but only Baetis intercalaris has undergone a substantial shift. B. intercalaris is described as a species of rapid water and Hallam (1959) found it associated usually with smallmouth and rock bass indicative of warm waters. When all Baetids were considered together there has been no change in the distribution of this family in the watershed between 1949 and 1984.

Of all the Ephemeropterans, Caenis spp. has undergone the largest reduction in distribution. This is somewhat surprising as it is an inhabitant of quiet or stagnant waters dwelling close to the bases of aquatic plants in the silt. Some Caenis species are described as tolerant of considerable pollution (Edmunds et al. 1976). Perhaps the paucity of rooted vegetation in this river as observed in 1984 may affect its distribution.

The heptageneids, Stenonema and Heptagenia have undergone moderate

reductions individually and major reductions as a group. All frequent the undersurface of rocks or hide amid vegetation which may now be subject to siltation or no longer a common habitat component. Heptagenia spp. and Stenonema vicarium are considered typical inhabitants of trout waters (Hallam 1959) and consequently pollution intolerant.

No real pattern exists for the tricopteran families Hydropsychidae or Limnephilidae. While both Hydropsychidae and specifically Hydropsyche spp. (net spinners) have decreased distributions slightly since 1949, the limnephilids, which are case builders, have increased slightly. However, limnephilids were not a common component of the watershed fauna in either year. Both families occur with equal frequency with cold and warmwater fish species (Hallam 1959).

The two odonates, Ishnura and Boyeria, have experienced very minor increases in distribution since 1949 from 3 to 6 and 5 sites respectively. The damsel fly Ishnura is considered pollution tolerant and is commonly found in depositional zones, while the dragonfly, Boyeria is considered pollution intolerant (Hilsenhoff 1977; Edmunds et et al. 1976).

Of the Dipterans, an increase in the distribution of chironomids and a decrease in simulids and syrphids were noted.

Chironomids were by far the most commonly found insect in the watershed. "The ability of chironomids to capitalize upon any available food items, to construct their own shelters, to thrive under a variety of conditions, combined with their great reproductive capacity, brief life cycle in most cases, and predominance in virtually all aquatic habitats makes the chironomids or 'non-biting midges' the most important group of aquatic Diptera in aquatic ecosystems" (Brigham et al. 1982). They are a common dietary component of many of the predominant fish species in the Don River. Although chironomids are also found in clean waters, they are considered pollution

tolerant and usually make up a large proportion of the benthic fauna in the heavily degraded sections of the Don.

Simulids are found in flowing water, usually in the swiftest part of the stream, and while these areas more often provide better water quality conditions than adjacent pools, waters with large quantities of suspended sediment were found to be unfavourable for most simulids as the suspended particles clogged both the primary fans and the digestive track (Brigham et al. 1982). Their decline may be related to the frequent and substantial suspended sediment loads in the river (OMOE 1983).

Syrphids, more specifically Eristalis spp. the rat-tailed maggot, were only found in 1949 at two sites both immediately downstream of the North Toronto STP. Their absence in 1984 speaks for the improvements made to the effluents over the years.

The amphipod Hyalella essentially has not changed distributions since 1949. However, the isopod Asellus is now much more widely found than in 1949. Similarly, Oligochaetes and leeches (Hirudinea) have both markedly increased their distributions. All are considered pollution tolerant and may be indicative of changing conditions in the watershed.

What the first two columns of Table 6 do not indicate is the relative contribution these organisms make to community composition i.e. the initial percentages are based on presence alone be it 1 or 100 individuals. In 1949, 13% of the 46 stations used in this analysis had a benthic community which was primarily pollution intolerant. In 1984 there were no sites where the majority of the fauna were intolerant. This suggests that although Plecoptera and Baetid distributions have not changed markedly, their relative abundance in the collections has.

Similarly, eleven stations (24%) no longer have a large proportion of the

fauna in the moderately-tolerant grouping. This loss is reflected by an increase in the number of sites now having a predominantly pollution tolerant fauna. Although species such as the rat-tailed maggot are no longer found downstream of the STP outlet, the distributions and relative abundances of oligochaetes, chironomids, leeches, isopods, and the amphipod Hyalella have increased at many stations.

4.6 Evaluation of Results

The biological information has been presented in two ways. Figures 3 to 8 depict the number of fish species (diversity; number of individuals caught is indicated at the top of the histogram) with BI results for 1949 and May and July 1984 shown with Hilsenhoff's water quality divisions. Appendix 7 lists all BI values by station. The number of individual fish caught is to be used strictly as an indication of relative abundance. Direct comparisons of numbers cannot be made because of the different sampling techniques. Each major branch or tributary is schematically represented by a line drawing of the water course with station locations plotted proportionally in downstream progression.

With each figure is a corresponding table presenting an evaluative view of fish and benthic species assemblages with a comparison to the BI water quality rating. Hilsenhoff's (1977) water quality divisions are reproduced on Table 7. Invertebrate assemblages characteristic of different types of water quality are listed in Appendix 5. Trout and sculpins are considered sensitive or pollution intolerant. Where a good diversity of species exists the assemblage was considered moderately-tolerant. These species were largely warmwater cyprinids, centrarchids and percids and those species previously flagged as having changed distributions. Pollution tolerant was assigned when essentially only 1 or more of the 4 most abundant species were present - white

TABLE 7. Hilsenhoff's water quality determinations from biotic index values.

Biotic Index	Water Quality	State of the Stream
1.75	Excellent	No organic pollution
1.75-2.25	Very Good	Possible slight pollution
2.26-2.75	Good	Some pollution
2.76-3.50	Fair	Significant pollution
3.51-4.25	Poor	Very significant pollution
4.26-5.00	Very Poor	Severe pollution

taken from Hilsenhoff 1977 but using revised values.

sucker, blacknose dace, longnose dace and creek chub.

Both evaluative formats are useful as fish diversity provides no indication of the sensitivity of the species present. A trout stream may have low diversity but is sensitive to environmental change. Additionally the BI only takes into account the arthropods present. At many sites over 50% of the sample may have consisted of molluscs and annelids many of which are considered pollution tolerant but are not given a BI value. Thus a BI calculated with only arthropods may result in a mis-leading water quality determination. Where the number of arthropods was less than 25 a very-poor rating has been assigned, superceding the calculated BI.

As with the fish species comparisons between years, the graphical representations have been grouped into tributaries or branches. Discussion of fish species diversity changes will be minimal given the already extensive treatment in Section 4.1.

4.6.1 Main Don River - Headwaters to Metropolitan Toronto

Figures 3a and 3b depict the change in fish and benthic community structure with downstream progression.

Fish generally exhibit reduced diversity and abundance between survey years and with downstream progression. Figure 3b shows that several sites have shifted from a moderately-tolerant fish assemblage to one that is considered pollution tolerant. The only site in the watershed with a sensitive fish fauna - cold water- has now shifted to one that is pollution tolerant.

Similarly the BIs are higher in 1984 than 1949 and generally increase with downstream progression suggesting poorer water quality conditions in 1984 and with downstream progression. Water quality conditions varied from

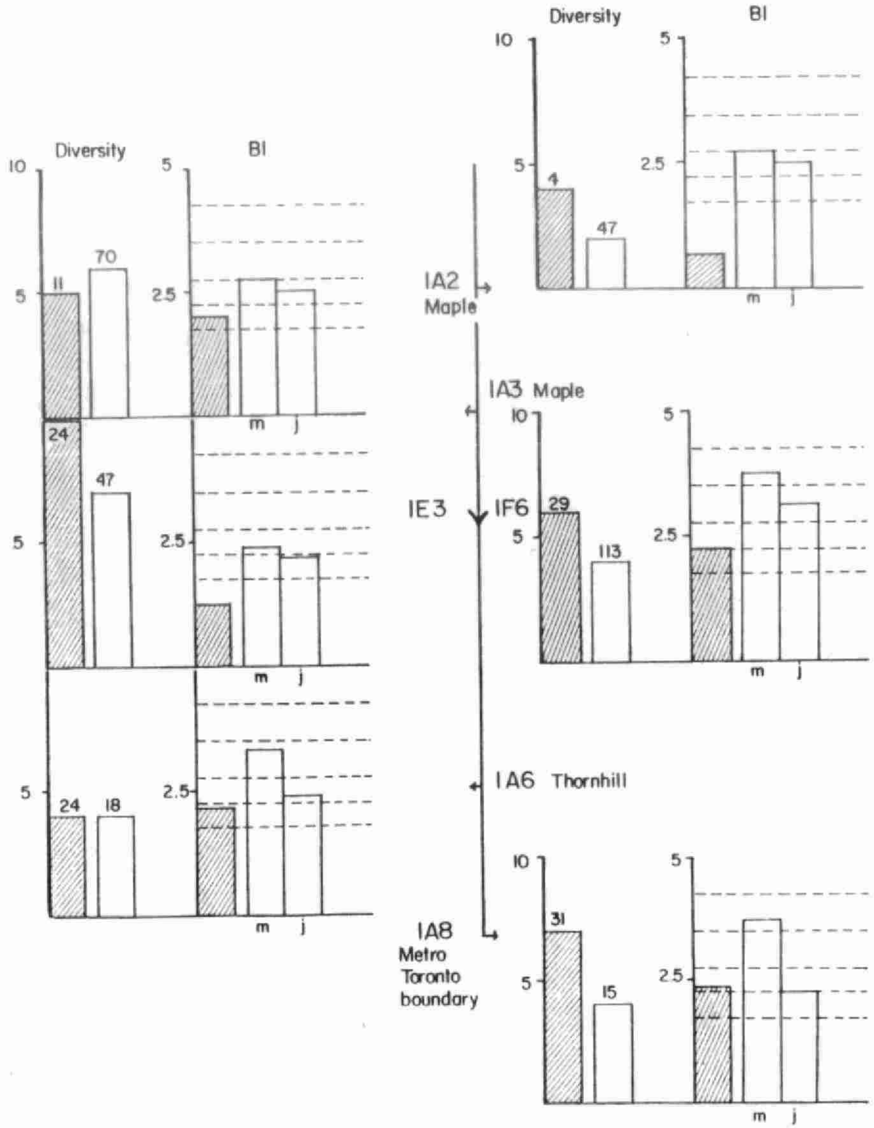

FIGURE 3A. Fish species diversity (no. of species) and biotic index values (shown with water quality divisions) for the Main Don River, headwaters to the Metropolitan Toronto boundary. The 1949 results are hatched. The number of individual fish caught is shown at the top of the column.

Station		Fish: Sensitive	Fish: Moderately Tolerant	Fish: Tolerant	Benthos: Sensitive	Benthos: Moderately Tolerant	Benthos: Tolerant	Water Quality: Rating
1A2	1949	○ BkT/MSc			○			○
	1984			●		◑		◑
1A3	1949		◑			◑		○
	1984		◑			◑		◑
1E3	1949		◑ RsD			◑		○
	1984		◑			◑		○
1F6	1949		◑			◑		○
	1984			●		◑		◑
1A6	1949		◑			◑		○
	1984			●			●	◑
1A8	1949		◑ RsD			◑		◑
	1984		◑			◑		◑

○ good or sensitive ◑ fair or moderately-tolerant
● poor or pollution tolerant

BkT = brook trout MSc = mottled sculpin RsD = redside dace

FIGURE 3B. Rating of fish and benthic species assemblages and water quality.

excellent-to-good in 1949 and good-to-poor in 1984. The evaluative index shows almost uniform very good water quality in 1949 with the exception of the farthest downstream reaches where conditions shifted to moderately-good. In 1984 however, conditions were uniformly moderately-good, with one exception at 1E3 where water quality is still considered good.

Species assemblages in both years were generally in the moderately-tolerant groups i.e. the largest percentage of species present fall into the moderately-tolerant groups which suggests reasonably similar faunas between years despite a low Jaccard Similarity Coefficient. At only two sites have assemblages shifted to be predominantly in the pollution tolerant group.

4.6.2 Main Don River - Metropolitan Toronto Boundaries to near Mouth

Once the river enters the boundaries of Metropolitan Toronto conditions worsen rapidly. The number of fish species decreased between years except in the furthest downstream reaches of this section where fish have now returned to areas previously devoid of fish. This is probably due to improvements to the sewage treatment plant effluent over the years. At most of the sites in this section the fish fauna has shifted from a moderately-tolerant to a pollution tolerant assemblage (Figure 4a and 4b).

The BIs indicate conditions substantially different from the upstream reaches. In both 1949 and 1984 water quality conditions ranged from good-to-very poor and generally the BIs indicated worse water quality conditions in 1984 than 1949.

At 1A14 an improvement in the July BI was observed suggesting improved water quality which is supported by a return of fish to this site. In 1949 this section was very badly polluted from the sewage outfall upstream and no fish were found (ODPD 1949). At 7A3 the BI indicates no change in water

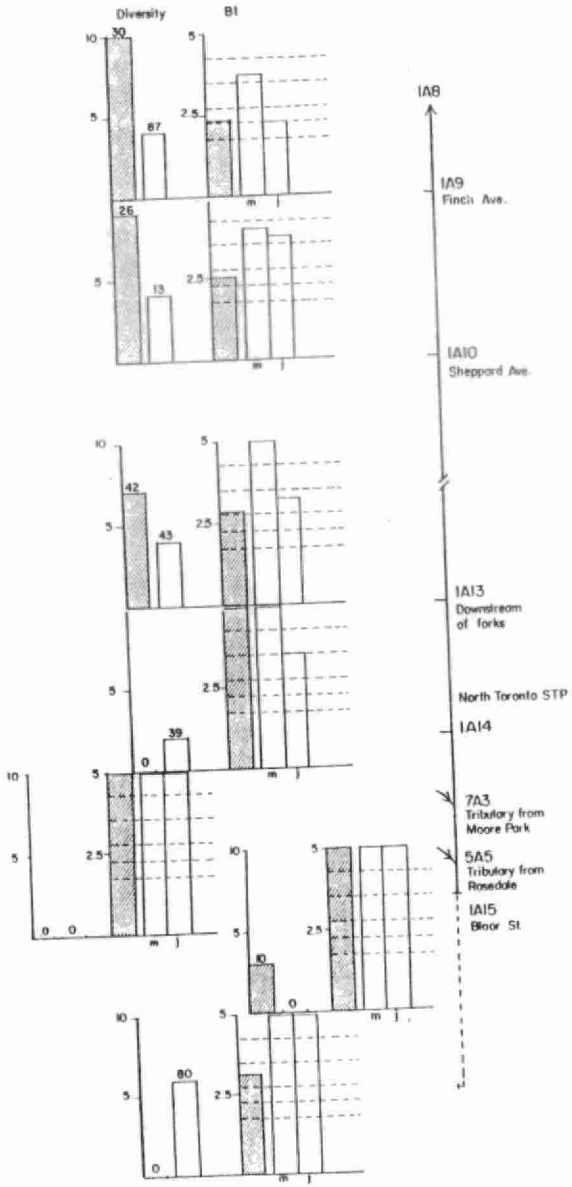

FIGURE 4A. Fish species diversity (no. of species) and biotic index values (shown with water quality divisions) for the Main Don River, Metropolitan Toronto boundary to near the mouth at Bloor Street. The 1949 results are hatched. The number of individual fish caught is shown at the top of the column.

Station		Fish: Sensitive	Fish: Moderately Tolerant	Fish: Tolerant	Benthos: Sensitive	Benthos: Moderately Tolerant	Benthos: Tolerant	Water Quality: Rating
1A9	1949		◐ RsD			◐		◐
	1984			●			●	◐
1A10	1949		◐			◐		◐
	1984			●			●	●
1A13	1949		◐			◐		◐
	1984			●			●	●
1A14	1949	no fish found					●	●
	1984			●			●	●
7A3	1949	no fish found					●	●
	1984	no fish found					●	●
5A5	1949			●			●	●
	1984	no fish found					●	●
1A15	1949	no fish found					●	●
	1984			●			●	●

○ good or sensitive ◐ fair or moderately-tolerant
● poor or pollution tolerant

RsD = redside dace

FIGURE 4B. Rating of fish and benthic species assemblages and water quality.

quality conditions and in neither year could fish be found. The 1949 field forms note that the highway was under construction and the stream had been redirected beside it. Although the BI's at 5A5 also indicate no change between years, there has been a loss of fish at this site which probably has been caused in part by the Don Valley Parkway interrupting the connection with the main-stream.

Surprisingly the BI for 1A15 does not indicate an improvement in water quality but fish have returned to this reach. The 1949 field notes described very heavy pollution at this site with the bottom sediments covered by a thick sewage mat. Such a condition was not found in 1984.

At sites where a moderately-tolerant benthos assemblage was present in 1949 the fauna has shifted to be predominantly pollution tolerant. The assemblages at the remainder of the sites remain pollution tolerant. Again the Jaccard Similarity Coefficients do not reflect the similarity of the pollution tolerant assemblages present in both years.

4.6.3 West Don River - Mainstream

In the upper reaches of the West Don River fish diversity has remained similar between survey years as has the community composition. By 2A4', at Highway 7 and still outside the Metropolitan Toronto boundary, the fish community has now undergone a considerable reduction in species and abundance which previously did not occur until well into Metropolitan Toronto (2A6). The fauna shifts from a moderately-tolerant assemblage including redside dace, considered a moderately-sensitive species, to a moderately-tolerant (without redside dace) group or pollution tolerant group (Figure 5a and 5b).

The shift to pollution tolerant forms first occurred in 1949 at 2A7 downstream of the two STPs which previously discharged to the West branch between Sheppard and Wilson Avenues. The 1949 field notes describe the stream

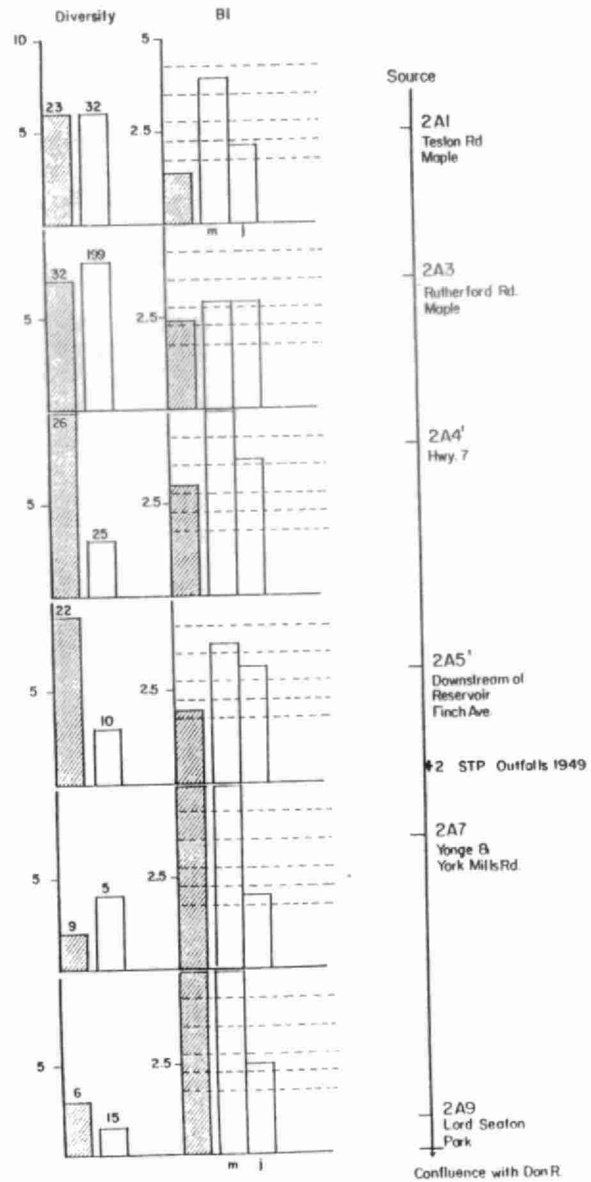

FIGURE 5A. Fish species diversity (no. of species) and biotic index values (shown with water quality divisions) for the West Don River, headwaters to the confluence with the Main Don. The 1949 results are hatched. The number of individual fish caught is shown at the top of the column.

Station		Fish: Sensitive	Fish: Moderately Tolerant	Fish: Tolerant	Benthos: Sensitive	Benthos: Moderately Tolerant	Benthos: Tolerant	Water Quality: Rating
2A1	1949		◑		○			○
	1984		◑			◑		◑
2A3	1949		◑ RsD			◑		◑
	1984		◑ RsD			◑		◑
2A4'	1949		◑ RsD			◑		◑
	1984			●			●	●
2A5'	1949		◑ RsD		○			○
	1984			●			●	◑
2A7	1949			●			●	●
	1984			●		◑		◑
2A9	1949			●			●	◑
	1984			●		◑		◑

○ good or sensitive ◑ fair or moderately-tolerant
● poor or pollution tolerant

RsD = redside dace

FIGURE 5B. Rating of fish and benthic species assemblages and water quality.

at this site as "an open sewer" with a considerable sewage carpet and odour. Although this condition was not found in 1984, the same species occur now in response to channelization which has taken place since Hurricane Hazel in 1954 at 2A7 and urbanization throughout much of this tributarys' watershed.

The BIs for the West Don indicate water quality conditions ranging from excellent-to-poor in 1949 and very good-to-very poor in 1984. The BIs were remarkably similar for several sites as evidenced by the water quality ratings on Figure 5b.

As noted with fish, by the time the river reaches Highway 7, only a few kilometers from its source, the benthic fauna is mostly composed of pollution tolerant forms rather than the intolerant or moderately- tolerant forms found in 1949. The farthest downstream site near the confluence with the Main Don (2A9) notes a shift from pollution intolerant forms to a moderately-tolerant benthic assemblage in 1984. This may be more an artifact of sampling than a real improvement in water quality or species change, although a small stream carrying dyes from a woolen mill entered at this site in 1949. Fish and invertebrates were taken immediately above the inlet but none could be taken downstream (ODPD 1949).

4.6.4 Taylor (Massey) Creek

Figure 6a and 6b depict the changes at two sites on this stream since 1949.

In 1949 at 3A4 only one species consisting of 2 individuals was captured and by 1984 no fish could be captured at this location.

As the number of individual arthropods with which the index would be calculated was less than 15 a very poor water quality determination has been applied. In May 1984 only 2 individuals of the sample were arthropods - the

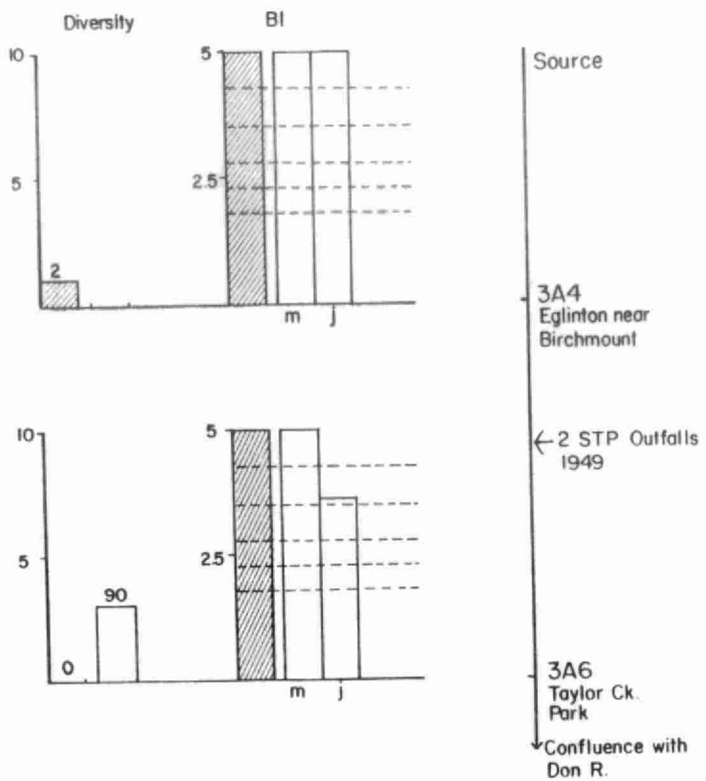

FIGURE 6A. Fish species diversity (no. of species) and biotic index values (shown with water quality divisions) for Taylor Creek. The 1949 results are hatched. The number of individual fish caught is shown at the top of the column.

		Fish			Benthos			Water Quality
Station		Sensitive	Moderately Tolerant	Tolerant	Sensitive	Moderately Tolerant	Tolerant	Rating
3A4	1949			●		◑		●
	1984	no fish found					●	●
3A6	1949	no fish found					●	●
	1984			●			●	●

○ good or sensitive ◑ fair or moderately-tolerant
● poor or pollution tolerant

FIGURE 6B. Rating of fish and benthic species assemblages and water quality.

remainder were oligochaetes and leeches. Thus on the corresponding figure the benthic assemblage has been classed as pollution tolerant.

Station 3A6 has improved aquatic conditions since 1949 probably attributable to the removal of 2 STPs which discharged upstream of this site. The stream was described as sewage polluted in 1949, no fish could be found and the only invertebrates were oligochaetes. In 1984 fish were found at this site, albeit a pollution tolerant fauna. The BIs also suggest a possible water quality improvement with the July sample only rated as poor. The species composition was predominantly chironomids and oligochaetes.

4.6.5 German Mills Creek

All sites have experienced a reduction in fish species diversity since 1949 (Figure 7a and 7b). All species present in 1984 were pollution tolerant forms while in 1949 species composition was considered moderately-tolerant in its downstream reaches and redside dace, reasonably sensitive to change was still found at several sites. The upper reaches however supported only pollution tolerant forms. The stream at this time was probably already influenced by the Town of Richmond Hill. It is thought that the stream was still above ground in 1949 while today it is piped under the town.

Water quality conditions varied from very good-to-very poor in 1949 and good-to-very poor in 1984. When the number of arthropods in the samples from 4A2 were considered, all years receive a very poor water quality rating. A benthic faunal composition of primarily pollution tolerant species and sparse number of pollution tolerant fish species found in 1949 confirms the very poor water quality designation.

At the remainder of the downstream sites analyzed on this stream the benthic fauna was primarily moderately-tolerant in 1949 and shifting in 1984 to pollution tolerant. Water quality determinations from the BIs remain

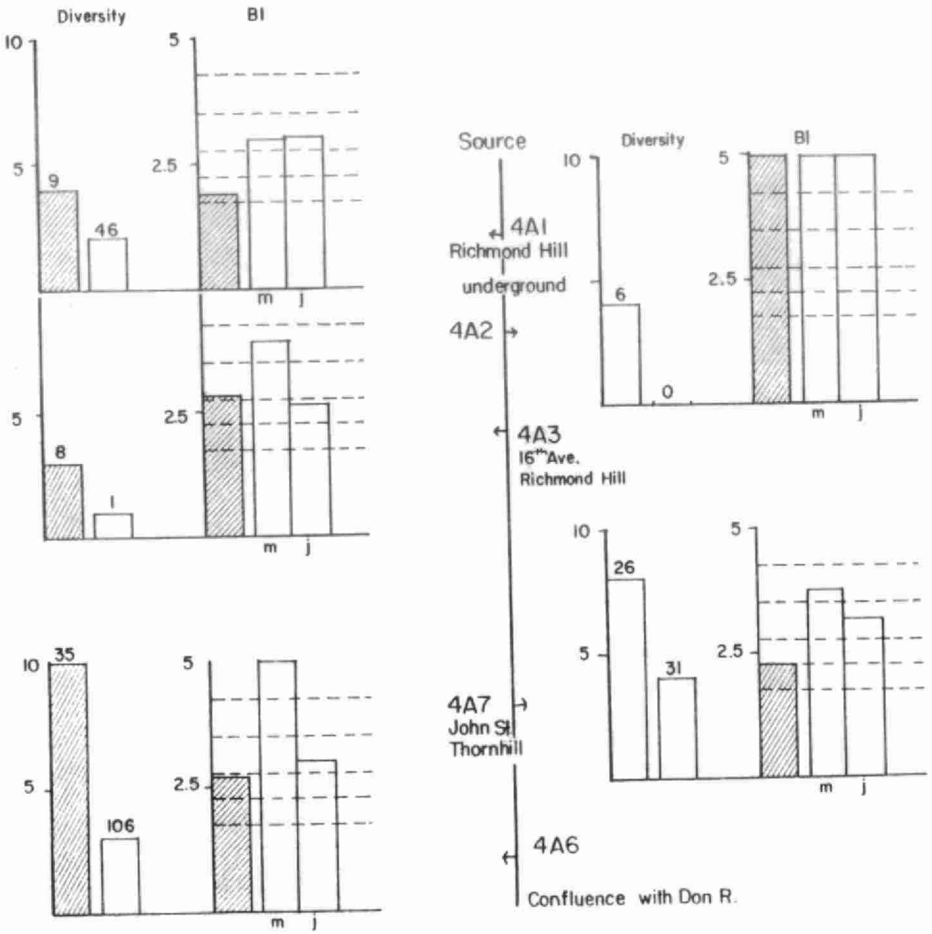

FIGURE 7A. Fish species diversity (no. of species) and biotic index values (shown with water quality divisions) for German Mills Creek, headwaters to mouth. The 1949 results are hatched. The number of individual fish caught is shown at the top of the column.

Station		Fish: Sensitive	Fish: Moderately Tolerant	Fish: Tolerant	Benthos: Sensitive	Benthos: Moderately Tolerant	Benthos: Tolerant	Water Quality: Rating
4A1	1949			●	○			○
	1984			●		◑		◑
4A2	1949			●			●	●
	1984	no fish found					●	●
4A3	1949			●		◑		◑
	1984			●		◑		◑
4A7	1949		◑ RsD			◑		◑
	1984			●			●	◑
4A6	1949		◑ RsD			◑		◑
	1984			●			●	◑

○ good or sensitive ◑ fair or moderately-tolerant
● poor or pollution tolerant

RsD = redside dace

FIGURE 7B. Rating of fish and benthic species assemblages and water quality.

largely in the fair or moderately-good rating.

4.6.5 Wilket Creek

Figures 8a and 8b depict fish and benthos information for 2 sites sampled on Wilket Creek.

Urbanized in 1949 as it is today, Wilket Creek was found dry in 1949 at the upstream site but to contain a reasonably abundant pollution tolerant fish fauna further downstream. In 1949, the ODPD noted that upstream of 8A2 (8A1) no fish or invertebrates of any description could be found. They suggested that this was possibly due to toxic ions from residential and industrial areas upstream. They found that raw sewage was pouring into the stream from an open sewer in a housing development and effluents from other pipes discharged to this creek at various points along its course. In 1984 no fish could be located at either site, although both appeared permanently flowing with fairly good habitat in a natural channel.

Water quality determinations were similar between years at 8A2, both years indicating poor-to-very poor conditions. The poor-to-very poor condition continues in 1984 at 8A3 supported by a pollution tolerant benthic assemblage but this sharply contrasts the good rating assigned to the 1949 sample. The benthic species assemblage supported this rating being predominantly in the moderately-tolerant group.

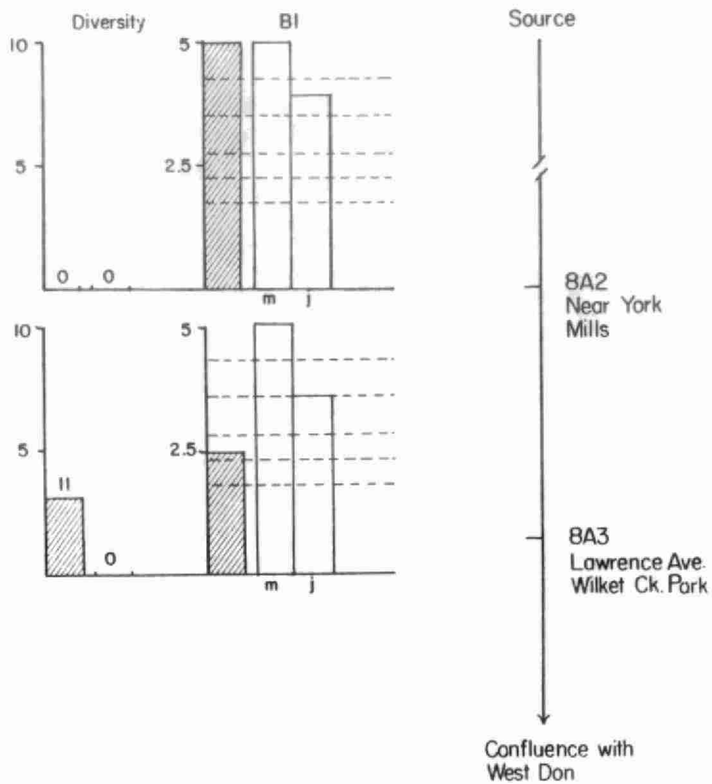

FIGURE 8A. Fish species diversity (no. of species) and biotic index values (shown with water quality divisions) for Wilket Creek. The 1949 results are hatched. The number of individual fish caught is shown at the top of the column.

Station		Fish: Sensitive	Fish: Moderately Tolerant	Fish: Tolerant	Benthos: Sensitive	Benthos: Moderately Tolerant	Benthos: Tolerant	Water Quality: Rating
8A2	1949	dry					●	●
	1984	no fish found					●	●
8A3	1949			●		◐		◐
	1984	no fish found					●	●

○ good or sensitive ◐ fair or moderately-tolerant
● poor or pollution tolerant

FIGURE 8B. Rating of fish and benthic species assemblages and water quality.

5.0 DISCUSSION

It is evident from the preceeding section that the present aquatic community has been severely impacted by cultural activities in the watershed. Neither cold nor warmwater game fish species utilize or inhabit this river, nor were any rare or unusual species located. Even many of the ubiquitous minnow species have been reduced or eliminated over the years.

Since its settlement, land use in the Don watershed was largely agricultural and by 1949 the impacts from these activities had long been reflected in the aquatic community. However, since the late 1940s agricultural land use has been steadily replaced by urban lands and thus the following discussion will center on changes in the watershed which are more likely to have accounted for the biotic shifts than continued agricultural activities.

Although supporting water quality and flow data have not been examined, two main causes of aquatic community changes have been strongly implicated: sewage treatment plant effluents and escalating urbanization bringing with it a host of complicating factors.

Sewage treatment plant effluents are chronically discharged often adding excessive quantities of nutrients, BOD, bacteria and organic and inorganic trace contaminants.

The impacts of sewage effluents on the aquatic community downstream have received considerable attention (Hynes 1960; Katz and Gaufin 1953; Krumholz and Minckley 1964; Larkin and Northcote 1969; Tsai 1973). Largely organic and nutrient-rich, untreated or inadequately treated sewage effluents are characterized by an immediate high oxygen demand. Although it was generally thought that sewage effluents exerted their influence on aquatic organisms principally through the depletion of oxygen, many studies have found that fish may be absent from the vicinity of outfalls even if oxygen conditions are

satisfactory. Undoubtably the oxygen content of water is of central importance; fish will detect and avoid water of abnormally low concentrations (Jones 1962). But Tsai (1973) states that dissolved oxygen may often not be the decisive factor in fish distributions. Tsai found that the number of fish species gradually increased below the outfall despite a decrease in dissolved oxygen. He suggests that this may be caused more by toxic effluents which exert their greatest effects close to the outfall and are diluted with downstream progression. Sewage effluent contains many toxic substances such as ammonia, sulphides, chlorine, cyanides, and carbon dioxide. For some of these, low oxygen concentrations exacerbate their toxicity (Hynes 1960; Larkin and Northcote 1969). For example, Thurston and Russo (1983) found that rainbow trout are more susceptible to ammonia toxicity at low dissolved oxygen concentrations. Thurston et al. (1984) also found that with exposure to chronic low levels of un-ionized ammonia, rainbow trout were not outwardly affected but the sublethal histopathological effects were abundant thus reducing their fitness.

Additionally, growths of sewage fungus and sedimentation may cover the substrate, blanketing spawning areas and food organisms, further influencing the distribution of fishes (Hynes 1960; Larkin and Northcote 1969).

Corresponding chemical data downstream of the outlets were not examined for the Don. However, evidence indicating poor effluent quality from 5 STPs operating in 1949 could be found in the aquatic community. At several sites in the watershed, notably downstream of the North Toronto STP, 2 STPs on the West Don and the 2 STPs on Taylor Creek, the streams were described in the 1949 field notes as sewage polluted, having a considerable `sewage carpet' and odour. The sewage carpet, it is assumed, refers to a blanket of sewage fungus. Such conditions were subtantiated by the complete elimination or

extreme reduction of local fish fauna and a predominance of extremely tolerant benthic organisms capable of surviving very low oxygen conditions.

In the intervening years 31 STPs were opened and subsequently closed until only two, the North Toronto Plant and a small one operated by the Ministry of Natural Resources in Maple, remained in operation in 1984. Although there are no biological data for most of these STPs, once those operating in 1949 were upgraded or removed, the conditions downstream of these plants improved. Fish no longer avoid these reaches and the benthos exhibits a marginally better diversity, although still predominantly pollution tolerant. Complete recovery from the effects of the STPs will not be realized however, as these sites are also heavily urbanized receiving storm or combined sewer overflows.

The impacts on aquatic communities from urban runoff are not so neatly discernable. Among the commonly cited problems associated with runoff from urban areas are: significant concentrations of heavy metals, pesticides, oil and grease, bacteria, nutrients, chlorides, BOD and suspended solids; increasingly rapid storm runoff causing an increase in the frequency and severity of flooding, accelerated channel erosion and alteration of the stream bed and substrate; stream channelization; reduced base flows; and water temperature alteration (Klein 1979; Leopold 1968; Moffa et al. 1981; Sartor et al. 1974). Any number of these, acting singly or in combination may have significant impacts on aquatic biota.

Alteration of flow regimes, because of the rapid runoff associated with the large percentage of impervious surfaces found in urban areas, is one of the most severe consequences of urbanization and the fundamental cause of most of the urban aquatic problems.

Increases in runoff create changes in the magnitude and duration of the flow peak as well as the lag time to the peak (Leopold 1968; Mather 1981).

Stream channel stability is controlled by the number of rises in water flow and the concomitant sediment loads. Thus, stream channels undergo adjustments to accommodate new flow regimes. Banks erode, structural features are breached and eventually the channel must be mechanically widened, straightened and stabilized with concrete or gabions to pass flood flows.

An hydrologic evaluation (McLaren 1979) of the Don River found that this river exhibited some of the highest flows per unit area in the Toronto region. For 6 of 7 sites the time to peak flow was computed to be 2-3 hours while the remaining site on German Mills Creek took only 1-2 hours to peak. Consequently, coincident peaks would exacerbate the flooding problem.

Percentage increases in flows were also calculated for the Don based on present and future land use. Flow increases ranging from 5-67% for the 100 year storm were calculated for seven sites. The largest increases will occur above Finch Ave. on the West Don (50%) and in German Mills Creek (67%) with escalating development in the Towns of Vaughan and Richmond Hill. Increases in the order of 10-15% for all return frequencies including the regional storm were calculated for the lower watershed while Taylor Creek already 88% urbanized, will have the lowest (5%) flow increase. It must also be remembered, that with increasing imperviousness, floods, particularly the smaller annual ones, will have a greater return frequency. Leopold (1968) noted a four-fold increase in the number of flows equal to or exceeding bankfull stage (1.5 year return) when the watershed had become 50% sewered and 50% impervious.

Runoff volume also affects low flows as the greater the quantity of direct storm runoff, the smaller is the percentage available to replenish the groundwater (Leopold 1968). Klein (1979) found a strong negative correlation between the percent imperviousness of a watershed and the quantity of baseflow. Reduced baseflows adversely affect stream communities through loss

of cover, reduced velocities, alteration of temperature regimes, and diminishing the volume of water over obstacles such as riffles or dams.

Conversely, flood waters as they become more frequent, strain the resiliency of the stream community through repeated substrate scouring, cover displacement and drift or dislocation of benthos and fish eggs and larvae (Elwood and Waters 1969; Hoopes 1975; Klein 1979; Seegrist and Gard 1972). Both Seegrist and Gard (1972) and Hoopes (1975) note the inability of rainbow and brook trout eggs and young-of-the-year to withstand floods. Elwood and Waters (1969) noted a decline in brook trout following floods which decreased habitat by loss of cover and pools.

Four types of instream cover were identified and subjectively quantified in the Don - undercut banks, rock, log and trees, and vegetation and debris under which garbage was included. Table 8 illustrates the average percentage of each cover type per station and the number of stations where each cover type was found expressed as a percentage of the total number of stations. The values for the Don are compared with those for the Credit River (Martin 1982), a nearby but far less degraded watershed.

In the Don, rock, which is mainly rubble associated with riffle areas, accounted for an average one quarter of the habitat and was present at 91% of the sites. Rock comprised a similar proportion of the habitat in the Credit but was only found at 51% of the sites. Data for the Credit indicate a greater proportion of the habitat is logs and trees and vegetation and occurring at more sites. In the Don, the average 2.3% vegetation and debris per site is more debris than vegetation. While we reluctantly admit that shopping carts and car parts do provide some cover, they may be lodged in marginal areas, do not provide ideal substrates for benthos colonization and are usually too small to modify the channel.

TABLE 8. Comparison of the percentage occurrence of cover types in two Southern Ontario basins - the Don which is heavily urbanized and the Credit, a much less impacted watershed.

River	Cover Type: Undercut Bank	Rock	Log & Trees	Vegetation & Debris
DON RIVER				
$\bar{x}$ % cover	12.4	25.4	9.1	2.3
% of stations with cover type	55.6	91.1	62.2	28.9
CREDIT RIVER				
$\bar{x}$ % cover	13.2	19.9	13.8	8.6
% of stations with cover type	57.4	51.5	75.0	36.8

The importance of habitat to maintaining species diversity has been established (Angermeier and Karr 1984; Carline and Klosiewski 1985; Edwards et al. 1984; Gorman and Karr 1978; Hynes 1970). Wood debris or other large instream structures such as boulders or man-made deflectors influence depth, current and substrate characteristics. Large pieces may constrict the stream channel which enhances pool formation by increasing the erosion potential of the water. Angermeier and Karr (1984) noted that woody debris enhances invertebrate production by providing suitable substrates for colonization. Although they found that invertebrates would accumulate in the absence of wood, they are unlikely to withstand high flows.

Fish associate with instream structure for several reasons which may include protection from current, food (invertebrate) availability and camouflage from predators or prey. Removal of logs, trees and other obstructions either by deliberate channel alterations or flood flows, may reduce habitat heterogeneity and loss of pools which are the preferred habitat for most game fish and larger individuals. Angermeier and Karr (1984) noted that only small fish, mainly cyprinids, showed no response to debris removal. Alternately, providing instream structure has proved an effective way of concentrating fish and increasing diversity and abundance of fish and benthos (Carline and Klosiewski 1985; Edwards et al. 1984).

While habitat loss is a significant factor in the reduced diversity of the Don River fauna, habitat mitigation alone will not restore productivity. Carline and Klosiewski (1985) found that despite the creation of suitable habitat for centrarchids, only non-game species utilized it. They concluded that the limiting factor here was reproductive failure caused by fluctuating flow conditions. In studies of rivers with fluctuating flows, and including this study, the most successful species tend to be those with reproductive modes adapted to running water (e.g. creek chub, white sucker, blacknose

dace)(Carline and Klosiewski 1985; Klein 1979; Tramer and Rogers 1973). While the eggs and larvae of these species may be washed out by flood flows, they are not expected to be as vulnerable as the nest guarding centrarchids or other species which depend on still waters (Carline and Klosiewski 1985).

Similarly, vegetation is also important in providing food organisms and refugia from current and predators. Flood flows, which erode the channel, destabilize stream banks and alter the stream bed, also remove or prevent the establishment of instream vegetative cover. In the Don River vegetative cover was not an common habitat component. Fish species such as blacknose shiner, brook stickleback, common shiner, fathead minnow and johnny darter, which are now reduced in distributions prefer quiet and/or weeded waters, both of which may be in short supply now.

New subdivisions are usually developed on agricultural lands so streams in the vicinity would have already been subject to higher sediment loads and water temperatures. It is nevertheless true that during the construction phases of development, sediment yields are very heavy which contribute considerably to channel aggradation and bank erosion (Dickinson and Wall 1977). In fact, studies have found that subdivision or industrial areas under construction yield 10 to 250 times the amount of sediment normally contributed from rural areas (Leopold 1968). As development is completed and lands stabilize, sediment yield is reduced from heavy to low or moderate and channels stabilize (Dickinson and Wall 1977). An examination of the sedimentation rates in the Keating Channel at the mouth of the Don River (see Section 2.3) showed peak deposition between 1959 and 1961. Considerable fluctuation was observed in the late 1960s and early 1970s but slowed substantially in the late 1970s (Acres 1983) with decreased building pressure.

Nevertheless, substantial sedimentation is still occurring which was

painfully apparent when caged clams used for biomonitoring in the first year of the TAWMS study were completely buried by silt after just three weeks in the Keating Channel. Such large sediment loads reduce the ability of benthic invertebrates to colonize the substrate.

Alabaster and Lloyd (1982) enumerate four ways in which suspended solids act upon fish: "1. By acting directly on the fish swimming in water in which solids are suspended, and either killing them or reducing their growth rate and resistance to disease [however to kill a fish within a short period of time, extremely high concentrations, e.g. >100,000 mg/l, of suspended solids would have to be present], 2. by preventing the sucessful development of fish eggs and larvae, 3. by modifying natural movements and migrations of fish, and 4. by reducing the abundance of food available to the fish."

Several investigators have demonstrated the effects of sediment but mainly on salmonids. Sediment concentrations may cause avoidance reactions of turbid regions, slow growth, or directly affect trout and salmon survival by diminishing apparent velocity and oxygen concentrations within a redd resulting in poor yearly recruitment and a gradual shifting to species whose needs are better suited to the environment (Bisson and Bilby 1984; Peters 1967; Saunders and Smith 1965; Shelton and Pollock 1966; Sigler et al. 1982). However, Gradall and Swenson (1982) noted that creek chubs may be positively influenced by turbid waters.

Leopold (1968) cites the work of Pluhowski who found stream temperatures in the urbanized sections of Long Island, New York 5.6 to 8.4^{o}C higher in summer and 2.8 to 5.6^{o}C lower in winter than in the non-urbanized area of the island. Such increases may further exceed the temperature requirements for the various life history phases of resident fish and invertebrates.

Although these former agricultural streams had already been subject to some of the same contaminants now contributed by urban areas, urban stormwater

runoff has been likened to sanitary sewage, paricularly during the 'first flush' of a storm. Sartor et al. (1974) report figures comparing stormwater runoff quality from the first hour of a moderate-to-heavy storm to raw wastewater. Briefly, BOD, COD, Kjeldahl nitrogen and phosphates in urban runoff were 5, 11, 4, and 9 times greater than the concentrations of these variables, respectively, in raw wastewater. A larger problem in the Don River is the discharge of untreated combined sewage to the river during storm events. Waller and Novak (1981) estimate that during storm events combined sewer overflows and surface runoff together discharge BOD, suspended solids and phosphorus loads that are approximately 3.7, 19 and 1.9 times, respectively, those of secondarily treated (assumed) wastewater treatment plant discharges.

Sartor et al. (1974) also found significant quantities of heavy metals, particularly lead and zinc, and the chlorinated hydrocarbons pp-DDE and pp-DDT and PCBs in stormwater. Klein (1979) notes studies finding lead concentrations 10,000 to 100,000 times those of background levels. Similarly, pesticide loadings were 2.7 to 4 times greater than the same contributed from rural lands. The initial TAWMS study found lead, copper, zinc, cadmium, mercury and several PCB/organochlorine, organophosphate, triazine and chlorophenoxy/chloro-benzoic acid pesticides exceeded guidelines for the protection of aquatic life in the Toronto area watersheds (OMOE, 1983).

Unfortunately, the net effect of all these contaminants remains uncertain as data bases are limited and research lags behind the detection of urban contaminants. The factor controlling the concentrations, and potential toxicity of these parameters, is the frequency with which they are flushed off the street surfaces. Loading intensity has been correlated with antecedent cleaning time, whether by storms or mechanical means (Sartor et al. 1974).

Thus, toxic pulses may be a frequent occurrence and influence streams, especially the smaller ones, accordingly.

While the toxic effects of stormwater contributions to the Don River were not proven by observations of fish kills, the avoidance reaction of fish would appear to provide one of the most sensitive indices of water quality conditions, particularly where highly toxic substances are involved (Larkin and Northcote 1969). Few studies have described the compounding effects of chemical alteration of the river in addition to habitat loss and flooding on the aquatic fauna. Tramer and Rogers (1973) found that within-station diversity for urbanized streams in Toledo, Ohio, was dependent on local habitat and water quality conditions. They found that environmental perturbation, particularly chemical variation, cancels out the diversity enhancing effects usually associated with increasing physical heterogeneity as the stream progresses downstream (Sheldon 1968). Likewise, Gorman and Karr (1978) suggest that environmental stability appears to control community stability.

The smaller tributaries of Taylor, Wilket and German Mills Creeks, now are devoid of fish in reaches which could not be attributed to lack of habitat. Though frequent flooding could wash fish out of the stream, recolonization from downstream should occur rapidly, as long as physical or chemical barriers to migration do not exist. Recolonization of the upper reaches of German Mills and Taylor Creeks has not occurred and this is attributed to toxic contributions as other conditions appear suitable. It appears that Wilket Creek has been abandoned by fish. The benthic community at these sites has been reduced to a predominance of chironomids and oligochaetes which Winner et al. (1980) find is a predictable response to severe heavy metal pollution. They suggest that there appears to be a direct relationship between the percentage of the benthic community composed of

chironomids and the degree of heavy metal pollution.

In the mainstream and the West Don greater dilution capacity exists and the toxic effect may be reduced. Instead of a complete avoidance, the aquatic community exhibits a decrease in the number of species and the number of individuals. This is described by Cairns and Dickson (1971) as a characteristic response to toxic pollutants. Conversely, organic (i.e. sewage) pollutants generally eliminate the intolerant fauna which reduces species diversity, but the tolerant ones thrive and the number of individuals increase.

Thus we have seen in the Don River that as the flood flows, sediment loads and chemical contributions to the river became more frequent and of a greater magnitude, the aquatic community shifted in response. Continued or escalating levels of these environmental variables ensure no recovery, if not further deterioration of the aquatic fauna.

Given the ideal situation that some measure of control can be achieved to improve conditions in the watershed, we must be optimistic, yet realistic, about the potential for fisheries rehabilitation. It is unlikely that trout could ever be restored and even if suitable locations could be found they would be restricted to a few kilometers of the headwaters. Instead we must turn to hardier, warm water species capable of withstanding considerable environmental variation. Of the four hardiest species still widely found in the Don, larger creek chubs and white suckers are of some recreational value. However, the larger individuals need adequate cover which is presently not available.

More optimistically, some centrarchids could be encouraged but again, only if suitable flow and cover conditions were made available.

Species such as carp presently use the river to spawn and further

utilization by the migratory salmonids may be possible.

The main river and the West Don have the greatest potential for rehabilitation. The smaller tributaries such as German Mills and Taylor Creeks may be too severly impacted to be restored to productive streams.

6.0 REFERENCES

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APPENDIX 1. Species list for benthic invertebrates with Hilsenhoff's (1977) pollution tolerance values assigned.

EPHEMEROPTERA

Heptageniidae
- *Stenonema heterotarsale* 2
- *S. canadense* 3
- *S. tripunctatum* 3
- *S. fuscum* 1
- *S. vicarium* 1
- *Stenacron (=Stenonema) interpunctatum* 3
- *Heptagenia lucidipennis* 1
- *H. hebe* 1

Leptophlebiidae (=Paraleptophlebiidae)
- *Paraleptophlebia praepedita* 1
- *P. ontario* 1
- *P. mollis* 1
- *P. debilis* 1
- *Habrophlebiodes americana* 1

Baetidae
- *Baetis spp.* 2
- *B. brunneicolor* 2
- *B. tricaudata (=vagans)* 1
- *B. flavistriga (=levitans)* 2
- *B. intercalaris* 3
- *B. parvus* 2
- *B. mcdunnoughi* 2
- *B. rusticans* 2
- *Cloeon triangulifera* 2
- *C. rubropictum* 2
- *C. spp.* 2
- *Centroptilum bellum* 1
- *C. skokianes (group)*

Caenidae
- *Caenis spp.* 3

Ephemeridae
- *Hexagenia atrocaudata* 3

Siphlonuridae
- *Siphlonurus spp.* 2
- *Ameletus spp.* 0

Ephemerellidae 1

TRICOPTERA

Hydropsychidae 2
- *Parapsyche spp.* 0
- *Cheumatopsyche spp.* 3
- *Hydropsyche spp.* 3
- *H. betteni* 3
- *H. bronta* 3
- *H. slossonae* 2
- *H. sparna* 1

Helicopsychidae
- *Helicopsyche borealis* 2

Limnephilidae 2
- *Limnephilus spp.* 2
- *Neophylax spp.* 2
- *Frenesia spp.* 2
- *Platycentropus spp.* 2
- *Pycnopsyche spp.* 2

Lepidostomatidae
- *Lepidostoma spp.* 1

Leptoceridae
- *Triaenodes spp.* 2

Philopotamidae 2
- *Chimarra spp.* 2
- *Dolophilodes spp.* 0

Psychomyiidae 2

Phyrganeidae 2
- *Ptilostomis spp.* 2

Hydroptilidae
- *Hydroptila spp.* 3

PLECOPTERA

Nemouridae
- *Nemoura spp.* 0
- *Leutra spp.* 0

Perlidae
- *Perlesta spp.* 2
- *Perlesta placida* 2

Perlodidae
- *Isoperla spp.* 0

MEGALOPTERA

Corydalidae
- *Chauloides spp.* 2
- *Nigronia spp.* 1

Sialidae
- *Sialis spp.* 2

ODONATA

Coenagrionidae
- *Ishnura spp.* 4
- *Argia spp.* 3
- *Enallagma app.* 3
- *Nehallenia app.* 3
- *Argion spp.* 3

Calopterygidae
- *Calopteryx spp. (=Argion ?)* 2

Aeshnidae
- *Aeshna spp.* 3
- *Boyeria spp.* 1
- *Anax spp.* 3

APPENDIX 1 continued

Lestidae
  Lestes spp. 3
Libelluidae
  Libellula spp. -

DIPTERA
Chironomidae 4
Simulidae 2
Ceratopogonidae 3
Tabanidae 3
Empididae 3
Muscidae 2
Ephyridae 3
Dolichopodidae 2

Stratiomyidae x
  Stratiomyia spp. x
Tipulidae 2
  Tipula spp. 2
  Antocha spp. 2
  Dicranota spp. 2
  Pseudolimnophila spp. 1
  Limonia spp. 2
Syrphidae
  Eristalis spp. 5
Athericidae
  Atherix spp. 2
Culicidae
  Culex spp. x

COLEOPTERA
Elmidae 2
  Ancryonyx spp. 2
Hydrophildae x
Tropisternus spp. x
Dytiscidae *x*
  Laccophilus spp. x
  Acilius spp. x
Haliplidae x
Gyrinidae 2
Dryopidae 2
Psephenidae 2
Scritidae -

COLLEMBOLA
Entomobryidae

NEUROPTERA
Sisyridae *x*
  Climacia spp. x

HEMIPTERA
Notonectidae
  Notonecta spp. x
Gerridae
Corixidae

LEPIDOPTERA
Noctuidae -
Pyralidae 1

AMPHIPODA
Talitridae
  Hyallela azeteca 4
Gammaridae
  Gammarus spp. 2
  Crangonyx spp. 4

ISOPODA
Asellidae
  Asellus spp. 5

DECAPODA -
Astacidae -
  Cambarus robustus -
  Orconectes propinquus -
  O. virilis -

GASTROPODA -
Physidae -
  Physa spp.-
Lymnaeidae -
  Fossaria spp. -
  Stagnicolor spp. -
  Lymnaea spp. -
Planorbidae -
  Helisoma spp. -
  Gyraulus spp. -
Ancylidae -
  Ferrissia spp. -

PELECYPODA -
Sphaeridae -
  Pisidium spp.-
  Sphaerium spp. -

ANNELIDA -
Oligochaeta -
Hirudinea -
  Glossiphonia spp. -

TURBELLARIA -
  Planaria spp. -

- = no value assigned   x = not to be included in analysis

APPENDIX 2. Fish inventory data for 1949 Ontario Department of Planning and Development (ODPD 1950)

Station	61	80	163	182	184	198	200	208	209	210	211	212	233	281	313	337	341	381	Species Total	
										Species Code										
1a2		2		1						5								1	4	
1a3			2	1		1				2		5							5	
1a4				1		3				2	5	6							5	
1a5			2		2	2			1	1	3	1				7	3		9	
1a6										3	9	9					3		4	
1a7						2			1	2	4	4				8	5		7	
1a8					1	4				3	5	2				12	4		7	
1a9			1		2	3			3	3	3	4		2		4	5		10	
1a10			1			5		1	6	1	3	1				3	5		9	
1a11						2		1	2							2	4		5	need gillnet to sample
1a12			2			5			5	2	1	4				7	5		8	
1a13						3			8	6	8	4				9	4		7	
1a14																			0	very polluted
1a15																			0	very polluted
1a16																			0	very polluted
1a17	1								1										2	
1b1									2			1		5					3	
1b2									2			4		5					3	
1b3			2	1	1	2			6	4	1	4		1			2		10	
1d2				3					2			2							3	
1e1										11									1	
1e2										6		2							2	spring nearby
1e3		1	2	2	4	4			4	3	1	2					1		10	
1e4			2	4	1	4				3	3	5					4		8	report trout in pond nearby
1f1																		7	1	appears excellent for trout
1f2				3						3									2	some springs, may dryup
1f3			1							2		9			1				4	turbid water
1f4				2	1	8				4		4					6		6	
1f5			2			3				4		9	1				9		6	
1f6			3		2	3				5		10					6		6	

Appendix 2 continued.

										Species Code								Species	
Station	61	80	163	182	184	198	200	208	209	210	211	212	233	281	313	337	341	381	Total	
1g1			1	4					5	2		3					4	2	7	
1g2			2	1	6	1				8		6					7		7	
1g3			2		5	3			1	7		8					4		7	
1h1										7		3							2	
1j1												1							1	standing pool
1k1										8									1	
1m1																			0	springs; cattle pollution
1m2									11			3							2	
2a1			2	1				8		5		3					4		6	
2a2			2	4	1	6		5		2		3					6		8	
2a3				3	4	4		8		2		2					9		7	
2a4			2	1	3	5		3		2		2				8	5		9	
2a4'			2	3	2	3	2	4		3		4				2	1		10	
2a5			3		6	3		4		11		2				1	4		8	
2a5'			1		1	2		3		4	2	2				6	1		9	
2a6			4	1	3					1	5	1				2	3		8	
2a6'			2		1	4				5	4	1				2	4		7	
2a7										4	5								2	stream is open sewer
2a8			2						1	2	5	5							5	
2a9									3	1		2							3	
2a10			2			2				4	5						1		5	
2a11			2						6	3	2						1		5	sewer dumps silty water
2b1			1	4		2	4	2		3		1					1		8	
2b3			1	4		1		1		7		2					2		7	standing pools
2b4			2	3	2	4		3		3		1				2	5		9	
2c1					2			2		7		5					6		5	
2c2			1	2		4				5		5					3		6	
2c3								1		6		3					2		4	
2e2										2		4							2	standing pools
2f2										8		2		4					3	
2k1																			0	
2k2																			0	3 sewer outlets
3a2																			dry	

Appendix 2 continued.

Station	Species Code																		Species	
	61	80	163	182	184	198	200	208	209	210	211	212	233	281	313	337	341	381	Total	
3a3				3					4	1				2					4	
3a4									2										1	
3a5										1									1	
3a6																			0	very sewage polluted
4a1			1	1						4		3							4	
4a2			2			2			1	1									4	
4a3									1	3		4							3	
4a4			5			1			3	5	2	3					3		7	
4a5			1			3		1	1	3	2	2				5	3		9	
4a6			2		4	4		5	3	4	3	3				4	3		10	
4a7			3		5	3			4	1		6				1	3		8	
4b1									3										1	
4b2																			0	
4b5			1	1	1	1		1	2	1	1	1				1	2		11	
5a4																			0	no fish found
5a5									5	3		2							3	
6a1																			0	lye pollution from sewer
6a2																			0	water polluted
7a2																			NC	no fish taken=no collection?
7a3																			NC	
8a1																			0	no fish found-sewage from upst?
8a2																			NC	
8a3			4							5		2							3	
8a4			3							3		3							3	
9a2																			0	poll. carpet; odour; no fish found
9a3																			0	enters pipe; no fish found
9a4										1									1	little cover

APPENDIX 3. Fish inventory data by station for 1984 Don River survey.

Station	163	181	182	184	196	198	201	208	209	210	211	212	281	313	331	337	341	381	# Species	Length Shocked
										Species Code										
1a2			87							60									2	25 m
1a3	14							2		14	3	34			3				6	35 m
1a4	4		1							11	3	17							5	45 m
1a5	13									16	85	12					5	7	6	75 m
1a6	3									1	6	8							4	60 m
1a7	8									4	16	12					3		5	75 m
1a8	8	1										3					3		4	100 m
1a9	5									7	71	4							4	60 m
1a10	+									4	13	1							4	40 m
1a13	2									1	39	1							4	≈50 m
1a14	3										36								2	65 m
1a15	11								13	4	48	2	2						6	65 m
1a17	3				10		29												3	3 seine hauls
1b3	5		2			2			2	3		38	1	1			1		9	50 m
1e3	2		2			1				14	4	18					6		7	50 m
1e4	10					4				12	33	12					3	+	7	≈50 m
1f1										2								4	2	≈50 m
1f4				2						6		62		2					4	60 m
1f6	2									53	18	40							4	60 m
1g2			8							73		61					2		4	60 m
1g3										18	1	25							3	25 m
2a1	1							27		4									3	≈25 m
2a2	1		1					1		5		6					3		6	35 m
2a3	4		1	3		3				122		35				1	30		8	≈30 m
2a4'	5									3		17							3	130 m
2a5'	3	5										2							3	110 m
2a6									1			4		2					3	75 m
2a7	1		1						2			1							4	100 m
2a9	10											5							2	75 m
2b3	5		1			2			1	17		43					27		7	180 m
2b4	1		1							6		7							4	50 m
2c1									1	9		17							3	25 m

APPENDIX 3. continued

Station	163	181	182	184	196	198	201	208	209	210	211	212	281	313	331	337	341	381	# Species	Length Shocked
										Species Code										
3a4																			0	60 m
3a6	10									2	78								3	80 m
4a1										27		19							2	50 m
4a2																			0	100 m
4a3										1									1	55 m
4a6										7	95	4							3	55 m
4a7	8									1	1	21							4	80 m
4b5												13							1	55 m
5a5																			0	85 m
7a3																			0	55 m
8a2																			0	50 m
8a3																			0	60 m
9a4																			0	45 m

+ = present but not counted

APPENDIX 4. Fish inventory data by station for 1984 Steedman Don River Survey

Station	Species Code 163	181	182	184	198	208	209	210	211	212	313	317	331	341	381	# Species	Effort
D1 (1f1)	1															1	387 second
D2 (--)																0	280
D3 (1a2)			33					41								2	463
D4 (2a1)	20		1			12		8		11				1		6	568
D5 (1f4)								1	1	34	8	4				5	609
D6 (1g2)			23	17				172	1	125				4		6	521
D7 (1a3)	31		1			1		12		7			1		1	7	444
D8 (1e3)	12		10					18		10				5		5	333
D9 (--)	19		47			40		45		64				3		6	350
D10 (4a4)		1								6						2	714
D11 (4a1)								95		38						2	770
D12 (2a2)	23					47		3		70				14		5	583
D13 (2b3)	3				2		6	7		27				9		6	642
D14 (4a5)	19							26	238	20	1					5	770
D15 (1a8)	7/2								0/1	2/4	1/1					3/4	seine/electrofish 836
D16 (1a5)	27				4			40	15	17				1	20	7	543
D17 (2a5)	1		2				2	15		6	1					6	889
D18 (2a6)							2			3	4					3	695
D19 (1a11)	7							41	79		1					4	760
D20 (8a3)																0	789
D21 (2a10)	36									57						2	601
D22 (2a9)	11								42	1						3	721
D23[a] (3a4)																0	829
D24 (1a12)	44							3	14	7	10					5	915
D25[b] (3a6)	2							6	62	1						4	699
D26 (1a15)	37						1	32	40	21	2					6	NA

a = downstream of site
b = upstream of site

APPENDIX 5. Benthic organisms classfied as to their level of pollution tolerance.

Tolerance level	Taxa	Reference
Intolerant	Plecoptera	
	Nemoura spp.	Hallam 1959;
	Leutra spp.	Hilsenhoff 1977;
	Isoperla spp.	Quigley 1981.
	Ephemeroptera	
	Baetis vagans	
	B. brunneicolor	
	B. mcdunnoughi	
	Stenonema vicarium	
	Paraleptophlebia adoptiva	
	P. debilis	
	P. praepedita	
	P. ontario	
	P. mollis	
	Habrophlebiodes americana	
	Ameletus spp.	
	Tricoptera	
	Parapsyche spp.	
	Hydropsyche sparna	
	Lepidostoma spp.	
	Dolophilodes spp.	
	Odonata	
	Boyeria spp.	
	Megaloptera	
	Nigronia spp.	
	Diptera	
	Tipulidae	
	Pseudolimnophila spp.	
Moderately Tolerant	Ephemeroptera	Hallam 1959;
	Baetis frondalis	Gaufin 1973;
	B. pygmaeus	Roback 1974;
	B. intercalaris	Hilsenhoff 1977.
	Stenonema canadense	
	S. bipunctatum	
	S. tripunctatum	
	S. heterotarsale	
	Cloeon simplex	
	Heptagenia hebe	
	Caenis spp.	
	Tricoptera	
	Philopotamidae	
	Psychomyiidae	
	Hydropsychidae	

Appendix 5 continued

Tolerance level	Taxa	Reference
Moderately Tolerant	Odonata *Enallagma spp.* *Ischnura spp.* Coleoptera Elmidae Psphenidae Diptera Chironomidae Amphipoda *Hyallela spp.* Gastropoda *Planorbis*	
Tolerant	Megaloptera *Sialis spp.* Diptera Syrphidae *Eristalis spp.* Culicidae *Culex spp.* Chironomidae Amphipoda *Hyallela azteca* *Gammarus spp.* *Crangonyx spp.* Isopoda *Asellus spp.* Gastropoda *Physa spp.* *Planorbis spp.* Limnaeidae Ancylidae Pelecypoda *Sphaerium spp.* *Pisidium spp.* Oligochaeta *Tubifex spp.* *Limnodrilus spp.* Hirudinea *Erpobdella spp.* *Glossiphonia spp.* *Helobdella spp.*	Brinkhurst and Cook 1974; Fuller 1974; Gaufin 1973; Harman 1974; Hilsenhoff 1977; Howmiller 1974; Hynes 1960; Quigley 1981; Roback 1974; Sawyer 1974.

APPENDIX 6. Jaccard Similarity Coefficients calculated for 1949 benthos data compared with May 1984 data and supplemented by July data.

Station	Jaccard Similarity Coefficient	Station	Jaccard Similarity Coefficient
1A2	0.091	2A1	0.375
1A3	0.261	2A2	0.346
1A4	0.182	2A3	0.438
1A5	0.400	2A4'	0.056
1A6	0.353	2A5'	0.400
1A7	0.412	2A6	0.300
1A8	0.176	2A7	0.667
1A9	0.158	2A9	0.111
1A10	0.158	2B4	0.118
1A11	0.063	2C1	0.222
1A12	0.071	3A4	0.429
1A13	0.200	3A6	0.500
1A14	0.143	4A1	0.304
1A15	0.143	4A2	0.286
1B3	0.250	4A3	0.389
1E3	0.250	4A6	0.286
1E4	0.250	4A7	0.136
1F1	0.438	4B5	0.214
1F4	0.267	5A5	0.200
1F6	0.240	7A3	0.143
1G2	0.154	8A2	0.143
1G3	0.188	8A3	0.091
		9A4	0.200

APPENDIX 7. Biotic index values calculated for the Don River benthic invertebrate data 1949 and May and July 1984 samples.

Station	Year	Calculations			
		$\Sigma n_i a_i$	N	Biotic Index	Rating
1A2	1949	69.2	100	0.69	E
	1984 m	277.7	100	2.78	F
	1984 j[a]	269.2	100	2.49	G
1A3	1949	199.9	100	1.99	VG
	1984 m	274.4	100	2.74	G
	1984 j	268.0	100	2.48	G
1A4	1949	168.4	100	1.68	E
	1984 m	254.3	100	2.54	G
	1984 j	238.6	100	2.19	VG
1A5	1949	245.8	97.1	2.53	G
	1984 m	364.5	100	3.64	P
	1984 j	277.8	100	2.58	G
1A6	1949	212.2	100	2.12	VG
	1984 m	334.3	100	3.34	F
	1984 j	257.4	100	2.37	G
1A7	1949	228.5	92.1	2.48	G
	1984 m	278.0	100	2.78	F
	1984 j	271.5	100	2.51	G
1A8	1949	232.5	100	2.32	G
	1984 m	373.3	100	3.73	P
	1984 j	242.4	100	2.22	VG
1A9	1949	248.9	96.5	2.58	G
	1984 m	425.0	100	4.25	P
	1984 j	332.5	100	3.12	F
1A10	1949	242.1	95.6	2.53	G
	1984 m	396.1	100	3.96	P
	1984 j	394.4	100	3.74	P
1A11	1949	265.1	91.8	2.89	F
	1984 m	415.4	100	4.15	P
	1984 j	not sampled			
1A12	1949	243.6	98.1	2.48	G
	1984 m	410.0	100	4.10	P
	1984 j	not sampled			
1A13	1949	244.5	86.6	2.82	F
	1984 m	-----	0	----	VP
	1984 j	336.1	100	3.16	F

APPENDIX 7 continued

Station	Year	Calculations $\Sigma n_i a_i$	N	Biotic Index	Rating
1A14	1949	-----[b]	1	----	VP
	1984 m	-----	5	----	VP
	1984 j	394.0	100	3.74	P
1A15	1949	277.5	88.9	3.12	F
	1984 m	-----	23	----	VP
	1984 j	-----	16	----	VP
1B3	1949	405.9	100	4.06	P
	1984 m	-----	8	----	VP
	1984 j	351.7	100	3.32	F
1E4	1949	178.8	100	1.79	VG
	1984 m	306.9	100	3.07	F
	1984 j	251.0	100	2.31	G
1F1	1949	144.0	96.8	1.49	E
	1984 m	305.8	100	3.06	F
	1984 j	220.9	100	2.01	VG
1F4	1949	228.4	100	2.28	G
	1984 m	380.7	100	3.81	P
	1984 j	223.4	100	2.03	VG
1F6	1949	216.2	96.1	2.25	VG
	1984 m	362.3	97.9	3.70	P
	1984 j	333.9	100	3.14	F
1G2	1949	212.0	92.0	2.30	G
	1984 m	309.4	100	3.09	F
	1984 j	405.2	100	3.85	P
1G3	1949	187.0	98.2	1.90	VG
	1984 m	294.4	100	2.94	F
	1984 j	354.6	100	3.35	F
2A1	1949	125.0	90.7	1.38	E
	1984 m	388.0	100	3.88	P
	1984 j	230.9	100	2.11	E
2A2	1949	283.7	100	2.84	F
	1984 m	304.5	98.4	3.09	F
	1984 j	269.3	100	2.49	G
2A3	1949	240.2	98.6	2.44	G
	1984 m	283.4	100	2.83	F
	1984 j	301.4	100	2.81	F

APPENDIX 7 continued

Station	Year	Calculations $\Sigma n_i a_i$	N	Biotic Index	Rating
2A4'	1949	273.7	93.3	2.93	F
	1984 m	-----	3	----	VP
	1984 j	387.5	100	3.67	P
2A5'	1949	186.1	93.2	1.99	VG
	1984 m	371.4	100	3.71	P
	1984 j	330.0	100	3.10	F
2A6	1949	210.0	100	2.10	VG
	1984 m	-----	7	----	VP
	1984 j	221.0	100	2.41	G
2A7	1949	-----	15	----	VP
	1984 m	-----	1	----	VP
	1984 j	221.0	100	2.01	G
2A9	1949	----	8	----	VP
	1984 m	----	2	----	VP
	1984 j	263.0	100	2.43	G
2B3	1949	not sampled			
	1984 m	275.0	100	2.75	G
	1984 j	371.5	100	3.72	P
2B4	1949	241.2	95.6	2.52	G
	1984 m	-----	3	----	VP
	1984 j	378.9	100	3.59	P
2C1	1949	232.2	100	2.32	G
	1984 m	-----	12	----	VP
	1984 j	376.1	100	3.56	P
3A4	1949	-----	13	----	VP
	1984 m	-----	2	----	VP
	1984 j	-----	5	----	VP
3A6	1949	-----	0	----	VP
	1984 m	-----	10	----	VP
	1984 j	379.4	100	3.59	P
4A1	1949	190.2	100	1.90	VG
	1984 m	295.1	100	2.95	F
	1984 j	323.8	100	3.04	F
4A2	1949	-----	7	----	VP
	1984 m	-----	3	----	VP
	1984 j	-----	18	----	VP

APPENDIX 7 continued

Station	Year	Calculations $\Sigma n_i a_i$	N	Biotic Index	Rating
4A3	1949	266.3	95.2	2.80	F
	1984 m	390.8	100	3.91	P
	1984 j	287.0	100	2.67	G
4A6	1949	249.7	95.2	2.62	G
	1984 m	-----	5	----	VP
	1984 j	320.0	100	3.00	F
4A7	1949	224.3	99.2	2.26	G
	1984 m	369.7	100	3.70	P
	1984 j	335.2	100	3.15	F
4B5	1949	191.7	94.6	2.03	VG
	1984 m	-----	6	----	VP
	1984 j	304.6	100	2.85	F
5A5	1949	-----	16	----	VP
	1984 m	-----	0	----	VP
	1984 j	-----	11	----	VP
7A3	1949	-----	12	----	VP
	1984 m	-----	1	----	VP
	1984 j	-----	11	----	VP
8A2	1949	-----	13	----	VP
	1984 m	-----	0	----	VP
	1984 j	400.0	100	3.80	P
8A3	1949	213.3	100	2.29	G
	1984 m	-----	3	----	VP
	1984 j	369.4	100	3.49	F
9A4	1949	-----	6	----	VP
	1984 m	-----	8	----	VP
	1984 j	398.6	100	3.79	P
1E3	1949	118.0	100	1.18	E
	1984 m	238.4	100	2.38	G
	1984 j	239.1	100	2.19	VG

[a] seasonal correction factor applied to July sample ; 0.2 subtracted from calculated biotic index

[b] number of arthropods less than 25 so very poor quality assigned

E = excellent, no organic pollution
VG = very good, possible slight pollutio
G = good, some pollution
F = fair, significant pollution
P = poor, very significant pollution
VP = very poor, severe pollution